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TURE STUDY LESSONS

by J. B. Philip

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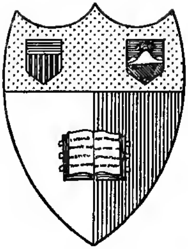

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Setting bulbs in autumn.

NATURE STUDY LESSONS

SEASONALLY ARRANGED

BY

J. B. PHILIP, M.A.

Cambridge:
at the University Press
1916

PREFACE

SEVERAL considerations have determined the choice of matter in the following chapters. In the first place the objects described, whether whole plants or parts, are nearly all of good size, of clearly defined and typical structure, and, what is also of importance, easily obtainable.

In the second place the material has a distinct relation to the seasons. The chapters follow the annual cycle of the months and, as each is independent of the others, a start may be made at any point and the circle completed from it onwards. The first chapter is of a general nature and may be regarded as introductory to, or as summarising, the rest of the book. It may be pointed out that the seasonal arrangement is not merely a matter of convenience. The cabbage is not merely set down for study in winter because it can be got then, or because little else is available, but chiefly because it is an expression in plant form of the cessation of active growth imposed by that season. In the same way the seedling bean suggests the return of vigorous life associated with spring. The fulness and colour of summer is seen in leafy plants (such as wallflower) with their showy flowers, while not less distinctly do the ripening fruits and showers of seed point to autumn as a time of results. Such a division of the subject not only emphasises the yearly changes. It also emphasises the structure of the organism on which these changes react in so remarkable a manner. Sum up the bean as a seedling, the cabbage as a bud, the lengthening shoots of the horse-chestnut with their expanding leaves, the finely branched wallflower, the tulip with its notable flower, the apple with its seeds and embryos and you have in concrete form some of the most important features of the typical body of higher plants.

The book, it is hoped, may be found suitable for pupils from 11 or 12 to 14 in both primary and secondary schools. Each chapter if studied in detail contains enough for several lessons and the course should keep a class employed for a whole session even with more than one meeting a week. Should gaps occur they will be readily filled in by the teacher with supplementary work. For example, the acorn may be compared with the cocoanut, brussels-sprouts with the cabbage, the pea with the bean and so forth. It is surely a mistake to suppose that there is scarcity of material for the study of plants in winter. Some of the autumn flowers last almost till Christmas, and even in January, when things are at their lowest, we may study the branching of trees, cross sections of stems, bulbs, fruits and seeds, many vegetables, such as the turnip, the cabbage and the potato, not to speak of imported flowers and seeds sprouted indoors.

The method of study must be determined by the teacher, but it is suggested that some of the subjects can be best introduced by a demonstration lesson, followed by some of the practical exercises, before the chapter is read or discussed. The cabbage and the cocoanut if illustrated by good specimens lend themselves to this form of treatment. In the case of crocus corms and wallflower, pupils might be provided each with material and asked after unaided examination of it to make drawings and write their own descriptions. Afterwards they may compare their work with the account given in the book. If too much help is given the pages that follow will fail in their main object, which is, not to convey a certain amount of information, but to encourage pupils to observe and record facts and to draw conclusions from them.

To each chapter there is prefixed a list of the material required with a note (where necessary) of the quantity for a class of 24 pupils. A general list with fuller particulars will be found in the Appendix. Attention may also be called to the sets of questions and exercises. These are by no means exhaustive of the work that might be done in connection with each chapter, but if carefully answered and worked out would possibly require more time than is allotted to this subject. If so it will be necessary to make a selection.

The illustrations are chiefly from photographs by the author. The chapter dealing with crocus corms originally appeared in the *Practical Teacher* and it is reprinted with the kind permission of Messrs Thomas Nelson and Sons. For leave to reprint instructions for the culture of snapdragons thanks are due to Messrs Dobbie.

J. B. P.

September, 1916.

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AUTUMN

CHAPTER I

THE PLANT AND ITS PARTS

Material required.

For demonstration.

A complete snapdragon or other plant with well developed branches and flowers.

For individual examination.

Two or three large plants of snapdragon will supply a class of 24 pupils with a sufficient portion each. If candytuft or shepherd's purse is used each pupil should have a whole plant.

In the following chapters various parts of plants are discussed such as stems, leaves, buds, flowers, fruits, seeds. In this chapter let us examine a whole plant and see how the above parts are put together to make it up. The separate parts which serve special purposes are called the **organs** of a plant and the whole plant made up of organs is called an **organism.**

A Plant as an Organism. We are much more apt to form wrong notions about plants than about animals. This is only natural, for the animals are like ourselves. Nobody needs to be told that the legs of a dog are for walking with, or that its eyes are for seeing and its ears for hearing. Other animals, it is true, have organs unlike ours, but to see them in use is often sufficient to suggest their purpose. We watch a trout propelling itself in the clear pool, and have no difficulty in realising the use of the tail, and as a bird makes its way through the air, we see the flapping wings and guess at once what they are for. With a plant it is different. It is stationary. There is no motion, no outward activity, and we wrongly conclude that it is doing nothing. If only we could have a plant magnified ten thousand times and at the same time made transparent so that we could see what is going on inside, then we should change our minds. Before us we should see a perfect hive of industry. In each leaf there are thousands of chambers called **cells**, workshops to all intents and purposes, in which living matter is vigorously manufacturing compounds that will go to feed the plant in every part. There are millions of these in a single plant. All this time the leaf is breathing even as we are, giving off a large amount of water in the form of vapour. This, of course, cannot go on unless the leaves are supplied with water, and if we could see the magnified stem and its hundreds of tubes, we should understand how this is done. The water supply of a city is directed to every street and to every house. In a similar way, only more perfectly, the water taken in by the root of a plant is distributed throughout its body. The more carefully we examine its parts the more convinced shall we become that every one of them renders to the plant as a whole some special service which we speak of as its **function**.

It is not only the functions of the various organs of a plant that we are apt to overlook. We may fail also to see how these organs are arranged. An animal has a very definite shape. It is built up on a plan which we see at a glance. There is the head, the body and the tail. In the higher animals the limbs are fixed on in pairs and the various organs in the head occupy definite positions. Even in animals so different as a dog and a fish, mouth and eyes have similar positions. In a plant we may fail to see any plan. All seems confusion. Again we make a mistake, which we shall discover presently.

At least two objects should be kept in view. We must try to understand the functions of all the parts, and secondly we must try and discover how everything is put together, in order to convince ourselves clearly that a plant is not merely an assortment of useless or inactive members, but an arranged **structure**.

GENERAL STRUCTURE

Choice of Specimen. We must now choose a specimen for examination, and we want a plant in which all the organs are shown—roots, stem, leaves, branches, flowers, fruit. Here we may explain that the word **fruit** is used in a scientific sense to denote the ripe seed-vessel of the plant whether it is edible like the apple or cherry, or inedible like the pods of the wild vetch or the hard three-edged nuts of the beech tree.

Some plants we shall reject in the meantime because they have got no branches, such as the tulip, or because their leaves are too crowded as in the daisy, or because their flowers are very irregular as in the dog's mercury or the orchis. There are, however, plenty of others of somewhat more regular type, from which a choice may be made. In the early part of the year we have wallflower (which is dealt with in a later lesson chiefly on account of its flowers). In summer we have buttercups of various kinds, foxglove (which, however, does not always show branches) and a host of others too numerous to mention. In autumn there are snapdragon and candytuft, both garden plants, of which the latter can easily be had in quantity by sowing seed out of doors in May or June.

Method of Examination. Take a good specimen of any of these in your hand, with all the organs present, including the root, and see what you can say about it. It is very easy to notice details such as the size of the leaf or the kind of surface the stem has or the colour of the flowers. Leave these comparatively unimportant facts alone in the first place and direct your attention to more general facts. Look at the plant as a whole. Place it in the position in which it grew and take a good look at it from a little distance.

Structural Plan. What are the plain facts that anyone can see? Surely one of the simplest is that its parts are well separated from each other. The plant is not all in a lump like a snail or a fish. The organs too are present in extraordinary numbers. It would take some time to count all the leaves or all the flowers on a well-grown snapdragon plant. In spite of their numbers look how well the parts are arranged, giving to the whole plant a handsome shape. There is nothing haphazard about it. The leaves are not attached at random. You do not find some of them growing out of other leaves and some from the root. All of them are fixed to the stem and its branches. The branches, which show great regularity in the direction of growth, do not grow from the root or from a leaf, but from the stem or from another branch. The flowers too come out in a definite order. The faded ones are not mixed up with unopened ones, nor are flowers in full bloom placed amongst those that have already turned into fruit, but the old ones are in one place (often lower down the stem) and the younger ones (often at the tip of the stem or its branches) are also all by themselves.

Classification of Parts. We very easily see by looking at the plant in a general way, that it may be divided into three—a lower brown portion (the root), a middle green portion where the leaves are, and the bright-coloured upper portion where the flowers are. The stem and its branches spread out in the middle part and hold up the leaves, and also connect these as well as the flowers with the root down below. We might go further with classification of parts, and taking the flowers and leaves, and of course also the stem and its branches from which they spring, as the **aerial** portion of the plant, that is the portion that grows in the air and is exposed to light, we should have the remaining part as the **subterranean** portion (the root). It must be noted, however, that in some plants the stem is underground as well as the root, as for example in the wood anemone. Then again we can give a reason for classifying the stem, branches, leaves and roots together as distinct from the flowers. The latter contribute in no way to the health and growth of the individual on which they are developed. In fact they actually detract from its vitality. Their sole function is to make new plants. Flowers therefore form the **reproductive** parts of a plant. All the other parts taken together form its **vegetative** portion. Without them the individual plant cannot thrive. There are also other ways in which the organs of a plant could be classified, as we shall see afterwards. In the meantime we shall examine the chief organs in order.

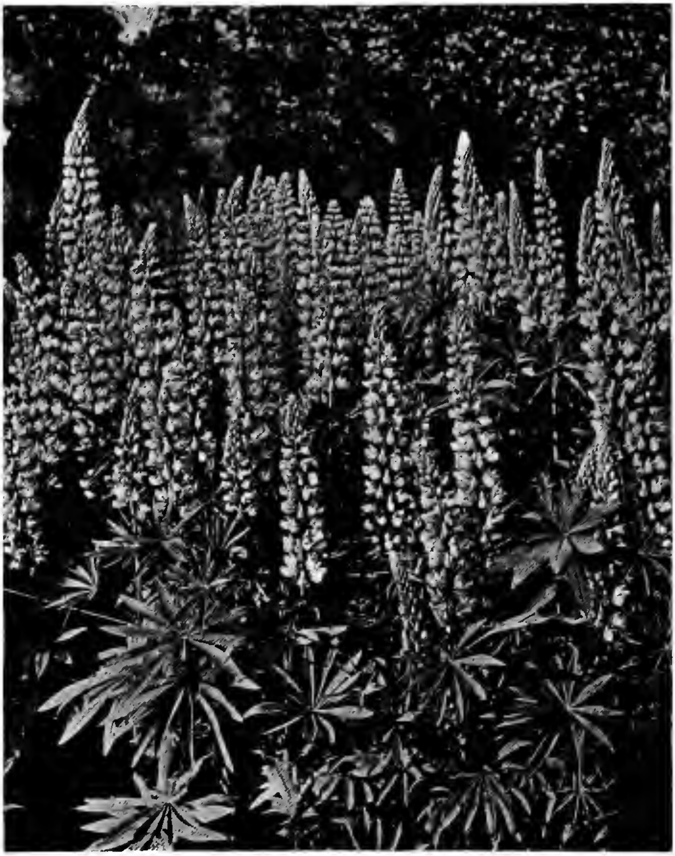

Fig. 1. Lupines. In this plant there is a clear distinction between the vegetative and the reproductive parts.

VEGETATIVE ORGANS

Root. We take the root first. Like the stem, the root has many parts, but these are not of so many kinds. In the middle and upper portions of the plant in addition to the stem and its branches, there are leaves and buds and all the variously shaped and coloured parts of the flower. In the root there seems to be nothing but **fibres**, differing in no respect, except direction and size, from the main part. This central portion can be easily seen growing downwards as a continuation of the stem—in candytuft for example, and in almost any annual plant. If the root is simpler than the stem in the kinds of parts it has, it certainly is not so easy to detect any definite plan of arrangement in the confused-looking mass of fibres. It is much easier to see what the root is for, and to see that it does its part very effectively. It keeps the plant in one place. A stationary position would be fatal to most animals but it is life to the plant, which may be killed by a single move. This notable difference between plants and animals depends on the way they respectively feed. The root then is the organ of attachment. It takes a grip of the soil, and a very firm grip too, for it requires an appreciable amount of force to pull up even a small plant, and big trees, with their splendidly developed root system, can generally maintain their hold even during a furious gale. But the root not only keeps the plant fixed so that it may feed, but actually does some feeding too, so far as the soil is the source of supply. It is the organ for collecting water—water containing material that has been dissolved from the soil. Let us try and picture the extraordinary activity of the root in this respect. Take an ordinary but well-developed root, and suppose it gives off ten branches, otherwise called fibres, and suppose each of these ten fibres has ten finer fibres (or **fibrils**) coming out of it. Further, observe that near the tip of each fibril there is a coating of fine **hairs**. Suppose that they number only one hundred, the root altogether would have ten thousand hairs. Each of these hairs is taking in from the soil a supply of liquid food. From the hairs the sap moves along the hundred fibrils, then along the ten fibres till it reaches the main axis up which it travels to the stem and eventually to every branch and every leaf, and, if there are flowers, to them also. The work of the root is therefore a benefit to the whole plant, and more than this, its activity, as long as the plant remains vigorous, is continually increasing. The stream of water that passes up the plant goes on by night and day, though not always at the same rate. As this liquid nutriment does not consist of pure water, that is of water as it falls from the clouds, we can see that it is of advantage for the root to be continually lengthening its fibres and fibrils, so that near the points as they get pushed further away hairs may be developed in fresh masses of soil, thus tapping new sources of supply.

Stem. As the stem differs from the root in bearing leaves and buds, in growing up instead of down, so it differs also in the service it performs for the general wellbeing of the plant. The stem, unlike the root, is not an organ of absorption. It has, however, some very important functions. The first of these, in which the root also shares, has been already referred to, namely, the distribution to the leaves of the supply of water with dissolved substances in it. This is accomplished by the action of various forces in the elaborate system of tubes and cells with which the stem is provided. But the stem has not only to raise the liquid from the root to the leaves. Another function is the removal of the food prepared by the leaves to all the parts of the plant that need it. Now would not all this moving about of materials be easier if the stem were shorter and the leaves consequently nearer to the water supply? The stem really seems to create as great a distance as possible between the root and the leaves. It shows a tendency to grow to the utmost length. Very often, even in small plants, it may be a hundred times longer than it is broad, whereas in the leaves the proportion may be only two or three times or less. This great growth in length, which of course is not accomplished without expenditure of energy on the part of the plant, has a distinct use. It enables the stem to perform a third very important function, that is, to lift the leaves out of the damp and dark, in which the roots in their cramped surroundings seem to thrive, thus allowing these broad green organs, which are generally well separated from each other, to be shone on by the sun and blown on by all the airs of heaven. Yet a fourth function has the plain but useful central axis of the plant to perform. It must act as a support to the leaves, branches and flowers, and it is wonderful how it develops as it grows a strength and an elasticity that make it able to bear the daily increasing burden of branch, of leaf, of flower, even under the extra strain of rain and wind.

Leaves. The functions of these organs have already been referred to. Let us now look more closely at their arrangement. It is plain that they occur mainly in the middle part of the plant. Here they appear to be pretty evenly scattered, but beyond this no plan is at first apparent. Look closer. Choose a straight piece of the stem or branch with a good many, say ten, leaves on it, and having fixed on one of the lower ones, find the first one above it that points in exactly the same direction. In many plants it will be found that between these two, four others intervene, all pointing different ways. There are thus five directions altogether, and if a line be traced on the stem from the base of the first leaf through the bases of the other four of the series and on to the base of the sixth leaf, which repeats the direction of the first (and is therefore the beginning of a new series), it will form a spiral occupying two turns of the stem. Such a disposition of leaves, known as the two-fifths arrangement, is a very common one. From these data we may calculate that the direction any leaf points in differs from that of its neighbour above or below by an angle of 144 degrees. Here then we arrive at the astonishing fact that a plant whose members outside seem to grow anyhow, has at least its leaves arranged on a plan of almost mathematical precision. We say *almost*, because in the actual case there will be slight deviations from the theoretical position, but these are not sufficient to alter the fact that every leaf that appears on the plant has its place fixed in accordance with the general plan. The systematic spreading of the leaves in different directions, be it two or three or five or eight, as well as their vertical distance from each other, secures for them a maximum of illumination. One of the most important functions of the leaf is the elaboration of food for the plant. In the small closed chambers (the vegetable cells) of which the leaf largely consists, the sap supplied by the root is brought into contact with the carbon dioxide derived from the air, and from these raw materials new compounds are made. Without these the plant would starve, and they can be formed only under the action of light. Now we see the need for an arrangement that will secure for each leaf as much light as possible. The large surface of the individual leaf shows the close connection between form and function.

Branches. As lateral extensions of the stem these might have been considered before, but there are reasons for the order here observed. In the first place the leaves appear on the stem before the branches, and in the second place the arrangement of the branches follows that of the leaves. In this latter fact we see a further development enabling the plant as a whole to get as much light as possible. Branches do not arise anywhere, but only above a leaf in the angle formed by it and the stem, that is, in the **axil** of the leaf. At first the branches are **buds** and we may watch the gradual passing of these into the tender shoot, with its soft green leaves all close together, and then into the perfectly formed branch, with the leaves well separated and ready to add by their activity to the resources of the plant. A fully developed branch differs from the stem in direction and size, but resembles it in its ability to branch again. Perhaps on some specimens you may be able to find a branch of a branch of a branch of the stem. If so, you will get some idea of the endless possibilities a plant has of extending itself. How strange it would seem if the higher animals could go on increasing the number of their limbs as they grew older! But there seems no definite limit in the case of trees, for some of them go on thickening their stem and increasing the number of their branches for two or three thousand years, as can very well be believed by examination of some of the remarkable cross sections to be seen in the South Kensington Museum in London.

As was pointed out at the beginning, it is easy, perhaps natural, to think wrongly of a plant, to look upon it, especially if it is a small one like candytuft or chickweed, as a poor, weak, straggling thing, incapable of accomplishing anything, seeming to exist, but not to live. Enough has perhaps been said to show that this is a wholly defective conception. A plant is the centre of ceaseless activity. Its organs are arranged on a definite plan and do definite work. More than that, the work of one kind of organ fits in with that of another. There is not only division, but also organisation of labour which results in the various energies collectively contributing to the health and growth of the plant as a whole. A plant therefore is a living, breathing, feeding, energy-producing organism.

REPRODUCTIVE ORGANS

The use of Flowers. We have now examined the chief vegetative parts of the ordinary plant—the root with its power to absorb, the stem which transmits the liquid supplies it receives from the root, and the leaf which transforms the raw material into useful compounds. No other organs are necessary for the vigorous health of the individual, for the flourishing condition that we associate with the proverbial green bay tree. If any proof of this is needed, we can point to the fact that plants that bear flowers may be healthy before the flowers come and healthy afterwards, or may go on without them for years. The flowers in fact help not the individual, but the species. By them new plants come. The seed is formed in the flowers. Nobody expects apples in autumn on an apple tree that has no blossom in spring. There can be no fruit, and therefore no seed, without a flower, and wherever we find a fruit, we may be sure there was previously a flower, as for example in the case of the oaks and beeches, whose fruits we know, but whose flowers we are apt to overlook. There are, of course, many kinds of plants that reproduce themselves without forming seeds. These have no flowers and belong to the great division of the vegetable kingdom known as **flowerless** plants. The other division includes all **flowering** ones.

Parts of the Flower. As the flower is so important a part of the plant, the names of its parts should be thoroughly known. If several flowers are carefully examined there ought to be no difficulty in understanding them. There are usually four sets of organs. On the outside (or underside) is a circle of small green leaf-like organs forming the **calyx,** each of whose parts is called a **sepal.** Then comes the most familiar part of all, owing to its size and bright colour. This is the **corolla,** consisting of **petals.** Many plants have five sepals and five petals, for example the harebell, the wild rose and the buttercup. Others have four, such as wallflower and candytuft. Inside the petals are the **stamens,** which may be as numerous as the sepals and petals taken together, in some cases more numerous still. The stamens are generally very easily recognised, having yellow heads growing from slender stalks. In these heads, or **anthers** as they are scientifically called, a fine yellow dust is produced, generally in great quantity. This is the **pollen.** All the stamens taken together form the **andrœcium.** Now we are at the centre, and here we find the seed-vessel or seed-vessels. This part of the flower is called the **pistil.** Here more likely than elsewhere in the flower confusion is likely to arise, for the pistil may consist of one seed-vessel or of more than one, and in the latter case they may be quite separated from one another, or they may be joined so as to appear, from the outside at least, like one. In the first place note that it does not matter how many or how few seed-vessels there are. All the seed-vessels together form one pistil. Next suppose a pistil consists of several separate seed-vessels and let us take one of these by itself for examination. It is usually green and consists of a swollen lower portion, the **ovary,** of a slender middle portion, the **style,** the end of which forms the third or highest portion called the **stigma.** These three parts taken together form one **carpel.** Inside the swollen portion when it is young we find one or more very small white or light-green bodies. These are **ovules** and later they may turn into seeds.

Seeds. Although the seeds are formed in the pistil as it ripens, it must be remembered that they cannot be formed without the co-operation of the other parts of the flower, especially of the stamens, as will be explained further on. The whole flower therefore is concerned in the formation of the seed. When the seed is ripe, the young plant or **embryo** will be found inside it. This gives rise to a new plant after the seed is sown.

RELATIONSHIP OF ORGANS

We have now spoken of most of the usual members of the plant body, as we find them in such common types as candytuft, wallflower, foxglove, snapdragon, buttercup, but some plants have organs or parts totally unlike anything yet mentioned. What about the strong and sharp **spines** with which gorse is so fully armed, what about **tendrils**, the delicate thread-like organs by which sweet peas cling to their support, **suckers** by which ivy fixes itself to the wall, **stings** that make one beware of touching a nettle, **sheaths** out of which daffodils emerge to flower, and so on? When we study the origin of these abnormal parts, we shall find that things are really simpler than they look. Instead of spines, tendrils, etc. being organs of entirely new types, they are only modifications of the old familiar ones. These strange looking parts are leaves or branches or hairs in disguise. How then are we to classify them? By a very simple process. By noting their relationship to the parts nearest them. We do not judge by outward form or by the function they perform, only by their position. Take one simple example. Suppose a tendril arises in the axil of a leaf (that is, between the leaf and the stem), it is surely in the very place usually occupied by a branch, and accordingly we decide that, in spite of misleading appearances, it really is a branch. If, on the other hand, a tendril grows out of the stem just below a branch, it is placed exactly where the leaf usually is, and so we settle that it really is a leaf and we call it a leaf-tendril. It finally comes to this, that the portions of a plant above ground are counted as one of three types—the leaf type, the stem type and the hair type. Even the flowers, apparently so different, do not escape classification with the rest of the members, for a flower is really a branch, and its parts, the sepals, the petals, the stamens, the carpels, are only modified leaves. Members belonging to the same type are said to be **homologues,** or, in the adjectival form of the word, **homologous.**

NOTE ON CHOICE OF TYPES AND METHOD OF STUDY

In this chapter snapdragon and candytuft have been mentioned as types from which a good general idea of the build of a flowering plant can be got. Local circumstances may suggest another choice.

Annuals that grow freely out of doors are to be recommended as they may be watched through all stages from seed to seed within a year. Among such are poppies, sweet peas, nasturtium, beans, balsam, Clarkia, convolvulus, Godetia, malope.

In the case of snapdragon it is best to sow the seed under glass and afterwards plant out the seedlings, which will probably flower the same season. In the case of plants that flower in their second year (such as wallflower, foxglove, Canterbury bell), seed may be sown each spring, and in this way pupils will be able to see both the earlier and later stages in the same session. Pupils who continue their study of the subject will of course be able also to trace the development of individual plants.

With trees only a small portion of the life-history of the individual can be followed. This, however, is no reason why acorns, chestnuts, etc., should not be sprouted in pots and afterwards grown out-of-doors.

If for example a few acorns were sprouted every season, there might be arranged in the school garden a series of young trees exhibiting a range of ages from one year upwards. In this way instructive observations could be made on the gradual growth in length and thickness and on the gradual extension of the plant body by branching.

Herbaceous perennials such as the primrose might be studied in a similar fashion, though of course the plants would have to be dug up to show the development of the underground stem.

If one type is used for class lessons pupils might cultivate and study another at home. This would enable them easily to record progress from week to week, and this, whether it is done by drawings or in writing or by both methods combined, forms a very useful exercise.

EXERCISES

[The plant used for this section should be one which grows in the school garden or close at hand and which can be obtained in quantity for several months of the year. The candytuft would be suitable. So would the snapdragon which has larger and bolder flowers. It may be necessary to arrange for sowing seed or setting plants some months in advance. The Exercises may be used either as an introduction or for revision at the end of the school year.]

1. Give brief definitions (of about two or three lines each) of:

(*a*) root.
(*b*) root fibre.
(*c*) stem.
(*d*) leaf.
(*e*) axil of leaf.
(*f*) bud.
(*g*) shoot.
(*h*) branch.
(*i*) flower.

of the specimen supplied.

2. Give a full description of any common plant. Any of the following will be suitable:

(*a*) buttercup.
(*b*) poppy.
(*c*) hollyhock.
(*d*) foxglove.
(*e*) wood anemone.
(*f*) harebell.
(*g*) candytuft.
(*h*) shepherd's purse.
(*i*) snapdragon.

The underground parts should in all cases be included.

3. Draw any complete plant and name all the parts.

4. Draw inflorescence of snapdragon (or other suitable plant) and alongside of it a single flower, a vertical section of flower, the ovary enlarged and a cross section of the last, also enlarged.

5. In many plants below each flower there is a leaf considerably smaller than the other leaves of the plant. This is called a bract. Show that its presence helps us to prove that a flower is really a branch. If the flower is a branch, then its various organs are really leaves in disguise. Give several reasons for believing that a petal is the homologue of a leaf.

6. Collect as many as possible of the following and make drawings to show organs which have wholly or in part undergone special modifications:

(*a*) pea.
(*b*) gorse.
(*c*) barberry.
(*d*) vetch.
(*e*) nettle.
(*f*) rose.
(*g*) hawthorn.
(*h*) potato.
(*i*) cactus.
(*j*) vine.
(*k*) monkshood (the flower).

In each case state the relationship of the modified part.

7. Take a small plant and support it with its root in water. If the water gets used up what conclusion do you draw? Make some arrangement to prevent the water from going off into the air by evaporation.

8. Dissolve some eosin dye in water and pour the solution round a plant in a pot. What happens? What does the experiment prove? The same might be tried on a cut flower, preferably a white one, *e.g.* white narcissus.

9. Put some fresh leaves under an inverted tumbler or bell-jar and leave them for an hour or two. Then examine the inner surface of the vessel and account for the result.

10. Cut off some leaves (which should not be too thick) and let them lie on the table till they have withered. Explain what is meant by this condition. Can they be revived? Try the experiment with leaves of different kinds.

11. Put some healthy leaves into a bottle quite full of water and cork it. Expose to bright sunlight for an hour or two. What do you discover at the end of this time? Try the experiment with several kinds of leaves.

If you have a good bed of **Snapdragon** or **Antirrhinum** in the garden you will be able to answer some further questions about this plant in particular:

12. Pick one flower each of as many different colours as you can find. How many colours have you? How many of these are self-coloured, *i.e.* of the same colour throughout? How many are bicolor, *i.e.* of two colours? How many are striped?

13. Describe in your own words each of the different colours you have found.

14. Write the names of all the red and yellow paints in your paint-box. Say which of these paints will be required to match the flowers. Will any other paints be required as well? Say for each flower described in question 13 what paint or mixture of paints you propose to use.

15. Measure and write down in inches and tenths the length of each flower picked. What is their average length?

16. What would be (*a*) twice, (*b*) thrice, (*c*) four times the natural length?

17. If you are making an enlarged drawing of the flower, what would be the greatest length you could take for the drawing on your paper? Could you make it still longer if the drawing were aslant across the paper? How many times natural length would this be?

18. Make a drawing of a snapdragon flower seen sideways at least four times natural size. Mark the parts you call "lip," "throat," and "upper petals."

19. Prick the pattern through on to 6 other sheets and prepare 6 more outlines.

20. Use a grey paint (how is this made?) or use black ink mixed with much water to paint the shadows as you see them in a white flower.

21. Paint the 6 outlines from question 19 to show the 6 other colours which you like best.

22. Measure the height of the Antirrhinums growing out-of-doors from the ground to the topmost flower. What is the greatest height? least height? average height? If over 2½ feet they are called "tall," 1½–2 feet "medium," and 9 to 12 inches "Tom Thumb." What name will you give to yours?

23. Here are some names of popular varieties: Amber Queen (canary yellow, overlaid chamois pink), Carmine Queen (rich rose carmine), Coccinea (intense orange scarlet), White Beauty (snow white), Yellow Queen (clear yellow), Nobile (white suffused crimson bronze). Which of these do you find?

24. Mark the plants you like best. Save seed from them, carefully keeping the different kinds distinct.

25. Hold a snapdragon flower sideways between your finger and thumb and pinch it so as to make it open its mouth. What do you see inside the throat of the flower (*a*) near the upper surface, (*b*) on the lower surface?

26. Take hold of a flower by upper and lower petals and hold its mouth agape. Tear it gently downwards to the base. How many stamens are there? How many styles? What do you find at the base of the stamens?

27. Is there any pollen on the anthers? Where else in the flower do you see pollen?

28. Watch a bed of snapdragon flowers in warm sunshine. Are any hive bees or butterflies visiting the flowers? What other insects are going to them?

29. Are the bees all alike? If not describe the different kinds.

30. On what part of the flower does a bee alight? How does it enter the flower? Can you see any pollen on it as it enters? as it emerges?

CHAPTER II

THE APPLE

Material required.

For demonstration.

Several large specially selected specimens showing variety of form and colour. One with clear division of the surface into five sides.

For individual examination.

Small apples (4 *to* 5 *lbs. for class of* 24) *which, after the external characters have been noted, may be divided so as to give to each pupil one vertical and one cross section. Apple blossom and very young apples preserved in spirit.*

If you wish to convey an idea of an object, its shape is one of the first things that should be stated. Shape and size are sometimes so easily stated that one is perhaps apt to overlook the importance of these particulars from their very simplicity. But shapes are not always so simple as they look. Take for example an ordinary apple. It is very easy to call it round, but if you do, you make two mistakes. You are in the first place ambiguous, and in the second, inaccurate; ambiguous because a circle, a pencil and a ball may all be said to be round, but they are very far from being of the same shape. The first is circular, the second cylindrical, the third spherical or globular. It is only the last of these adjectives that can be applied to the apple. Now we are definite, but without being correct, for the apple is only approximately of this shape. The surface sinks round the stalk and there is another depression at the opposite end of the same diameter. Even if those hollows were filled up, it would still be inaccurate to call the apple a sphere, because in many kinds at least the widest part is nearer to the stalk than to the other end, towards which there is often a distinct tapering which gives the fruit the form of an egg.

Just one observation more is needed to shatter this idea of the sphericity of the apple. This comes when we notice that even where it looks roundest it is really five-sided. It is true that this condition is not always obvious but in some varieties there is no difficulty whatever in detecting it.

The ends of the Apple. There is another little point on which doubt may arise, and that is the naming of the ends. Which end is the top? There is no doubt that when the apple is ripe, it generally hangs from its stalk and the end from which the stalk issues is as a matter of fact higher up than the end without the stalk. For all that we must not call this end the top, for this is not the original state of affairs, and has been arrived at by the weight of the apple causing it to turn downwards instead of standing straight up from the stalk, which it did in the earlier stages of its growth. The top of the apple then is the end without a stalk. This may seem a trifling matter, but if attention is not paid to it, confusion is sure to arise in a written description.

The External Characters. Having discussed the shape of the apple and the naming of its ends, let us look at the outside characters. We notice the green colour turning to red on one side, the absence of hairs, the smoothness and the polish. It is not sufficient, however, merely to note that these simple characters are present. We ought to discuss them. In some cases we may be able to suggest the cause that has produced the condition. In other cases we may see how it results in being of use. Sometimes we may suggest both cause and use. Take, for example, the red colour. Seeing that this occurs always on the side exposed directly to the sun's rays, we have little difficulty in believing that it is caused by sunshine. Now as to the use. The apple is an organ of the apple tree and as such has certain functions to perform, among them being the dispersal of the seed. How does the red colour help towards this end? Surely by making the apple more easily seen and therefore more likely to be carried off by animals which in eating it will unconsciously scatter seeds. Then there is the smoothness of the surface. The advantage of this is evident. After rain the apple will not remain long wet, as water readily runs off or is evaporated from a surface like this, instead of remaining and perhaps causing the fruit to rot. Other characters such as the greenness and the hardness may be dealt with in a similar way.

The Remains of the Flower. Before studying the inside of the apple, there is one thing more on the outside that must be examined, and that is the depression at the top. In it there is a number of minute objects apt to be entirely overlooked. Five of these, in a very small circle, have reached the brown and brittle stage when all activity has passed away. Their work whatever it was is done. These are really the shrunken remains of the sepals of the apple blossom which preceded the apple itself. If there is any doubt that the flower was here, it will be removed if within the withered calyx you can detect the withered stamens retaining to the last some semblance of their former distinctive shape. The apple has therefore been developed below the various floral organs whose remains we have discovered in the shallow depression. Fruits related to their antecedent blossom in this way are known as **inferior** fruits, inferior simply meaning lower down. To this class belong the gooseberry and the currant, where the husk represents the flower. It is natural to enquire why the blossom, which is in many plants below the fruit, appears in a different position in the case of the apple. But we must not let this question obscure the wider truth, that fruit is never found except where there was first a flower. The flower is the cause of the fruit. The fruit is the final stage of the flower. The stamens, petals and sepals must not be looked upon as ornamental accessories. They give real and necessary help. All are contributory in their respective ways to the formation of the fruit that follows them. Look on this picture and on that. Here we have the miserable remnant of a beautiful flower—shrinking sepals, dry twisted stamens, petals scattered to the wind—and here the rosy, plump apple, a picture of prosperity. This same apple, however, is a proof that the various outer organs of the spent blossom have not retired into nothingness until they have played their part in the scheme of things to very good purpose indeed.

The Stalk. Nor must we overlook the stalk. It is neither obtrusive nor attractive, but its function has been an important one. Till the apple was ripe, the stalk fixed it to the parent tree and acted as the channel by which arrived the bulk of the material now packed inside the apple and its seeds—the material that has changed it from the unnoticed centre of the flower to the big fruit it is. Nor did the service end there. As it was the stalk that kept the apple to the tree so it was the stalk that finally accomplished its fall. The severance of the apple's connection with the tree is worked out by the processes of growth just as much as the appearance of a blossom or the opening of leaf-buds.

Cross Section. Now we come to the inside of the apple, and to see its structure a section should be made, dividing the apple into an upper and a lower half. This gives us a cross or transverse section. The most prominent feature of the flat, cut surface, which is, of course, bounded by a circle of skin, is the part of the apple that nobody eats. This part, commonly known as the core, occupies the centre of the section and consists of a starlike arrangement of five cavities, each with its complement of seeds. The part of the apple which is most important or attractive to the general public, is, of course, the pulp or flesh, which, as the section clearly shows, fills up all the space between the skin and the core. In a drawing of the section one would never think of leaving out the core or the skin, but perhaps the flesh might be simply represented by a blank. This would not be satisfactory. Something has been omitted and that is a number of dots occupying definite positions and forming a circle that divides the flesh into an outer and an inner portion. These ten dots should certainly be represented in the drawing.

It is not difficult to tell the use of the skin, the flesh, and the hard core that surrounds the seeds, but what is the meaning of the apparently useless circle of dots? In order to understand this, we must stop a little and consider the relative positions of the floral organs in one or two types of flowers. The gardener may not like to have apple blossom picked in the orchard, but perhaps you can find a wild crab apple tree whose flowers you may pick. If these are gathered in May and June and also some very young apples shortly after the fruit has set, and preserved in methylated spirit, they will be ready for comparison with full grown apples in autumn. First look at Figure 2 (*a*). There the top of the flower stalk is shown with the various organs attached to it in the usual order. First come the sepals and last the seed-vessels. Each set of organs is a little higher up than the preceding set. In Figure 2 (*b*) this arrangement has been altered. The part of the flower stalk to which the sepals, petals and stamens are fixed, has grown out a little to the sides, with the result that these organs now arise on the same level as the seed-vessel. Just imagine that this side extension of the flower-stalk is carried upwards as well. That brings us to Figure 2 (*c*), where the sepals, petals and stamens originate higher up than before. In 2 (*d*) they arise on a level with the top of the seed-vessel. Finally, suppose that the cup-like part of the flower-stalk is in close contact with the seed-vessel it surrounds and that it has actually been united with it from the earliest stages. Then we have the condition of affairs which obtains in the apple. If this is so, the portion of the apple outside the ring of dots is really a part of the flower-stalk which has ripened and become edible in sympathy with the seed-vessels which it so closely encircles. The ring of dots is all that remains to show where the outside of the apple would have been if the

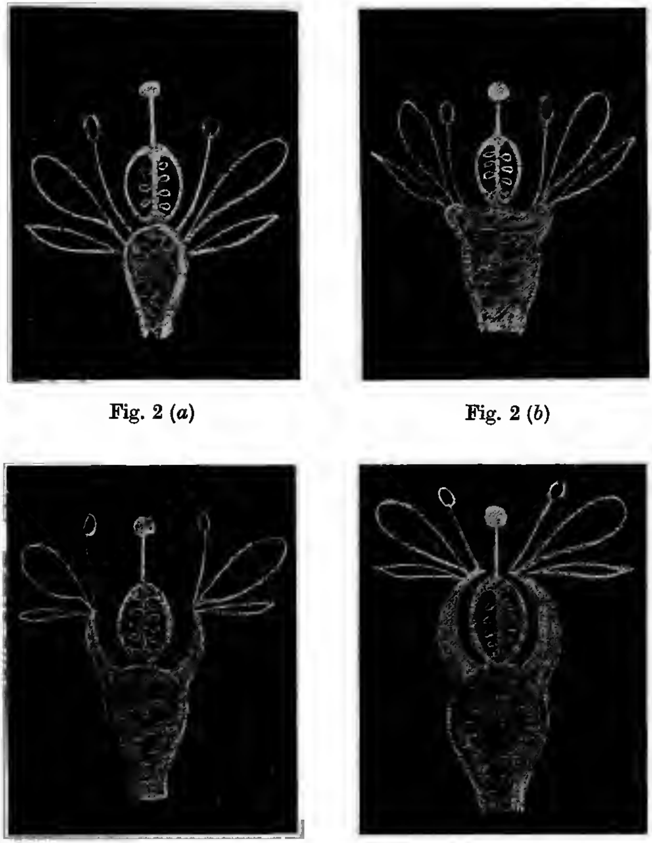

Fig. 2 (*a*) **Fig. 2 (*b*)**

Fig. 2 (*c*) **Fig. 2 (*d*)**

Diagrams showing varying relations between pistil and other floral organs. (From blackboard drawings.)

stalk had not grown up in union with the seed-vessel. In fact the dots and the faint curved lines that join them, are actually the skin of the seed-vessels (or carpels) in a very much reduced condition. This is the part of the apple that most naturally suggests the past. The seed is for the future, the green skin is functioning now, the faded flower represents a set of conditions that have just passed away, while the hidden skin takes us to a remote epoch, when some ancestral form really had an external surface where this faint indication of a line is still to be seen. This skin is therefore a **vestigial** structure. Examples of such structures are frequent throughout the animal and vegetable kingdoms, and most helpful they are when we wish to trace the origin of existing types of animals or plants.

The Seed. A vertical section (that is, a cut through the middle of the apple from the upper to the lower depression) should be made in order to show the position of the seeds in the core and their attachment by the lower and sharper end. The brown colour of the outer coat and the flatness of one side may be discussed in passing, but chief attention should be bestowed on the glossy object of an ivory whiteness which occupies the interior of the seed. Small and insignificant though it be, this is a whole plant. It is the baby apple plant, and the seed-coats form a cradle for it. Let us examine this embryo and prove that it already possesses some of the important parts of the full-grown tree. There is not much difficulty in finding the root projecting at the narrower end, but the stem, or rather the bud that will give rise to the stem, is not so easily seen. The insertion of the point of a knife on the line that runs along the edge of the plantlet, will separate two relatively large objects that previously lay with their flat faces close together. Between them and just above the root the stem-bud will be found. Next consider these objects themselves. What can they be but leaves? No doubt their colour and flatness make them rather unlike the ordinary thin, green foliage of trees. The resemblances, however, outweigh the differences. Their outlines, their veins, and chiefly the fact that they are lateral outgrowths from the stem, make it impossible to classify them otherwise than as leaves. As they differ so much from the leaves that appear later, they are known as seed-leaves or **cotyledons.** Compared with the root and stem-bud, their size is enormous. If a full-grown apple tree had its organs in similar proportion, the leaves would be at least several yards in length. Can you explain why the seed-leaves are so big and why they are pale in colour?

The Sowing of the Seed. When the young apple plant in the seed **germinates** (that is, begins to grow), it must, of course, be supplied with food until it is able to obtain supplies for itself from the soil and from the air, but do not make the mistake of supposing that it will feed on the flesh of the apple. If not for the embryo, what is the use of the flesh or pulp, the presence of which in many other fruits (not necessarily cultivated or edible) add by their colour to the glory of the mellow year? It is not only leaves that array themselves in bright colours as their work draws to a close, but the fruits also of hedgerow and woodland, like the wild rose and the rowan, carry something of the brightness of summer into the fading days of autumn. But all this beauty is incidental, for the colours are the means by which animals are attracted to the edible parts and unconsciously act as the scatterers of the seed of the fruits, illustrating thereby the interdependence of the vegetable and animal kingdoms, an interdependence that is often, though not always, an advantage on both sides.

EXERCISES

1. Draw (*a*) whole apple, (*b*) cross section (do not omit the ring of dots), (*c*) vertical section, (*d*) upper depression and surrounding irregularities of surface, (*e*) whole seed, (*f*) seed without the seed-coats, (*g*) embryo with cotyledons separated.

2. Write a description of an apple, dealing first with the outside, and then with the inside as seen in section.

3. Obtain several varieties of apple, and draw, to show the different shapes.

4. If you can procure some badly shaped apples, make cross sections and see if you can discover the cause of the abnormality.

5. Compare an apple with an orange, first externally and then internally. Note especially the two ends of the orange. If oranges are not available, take a plum instead. In the latter case note that the seed is inside the stone.

6. Draw a vertical section of the fruit of the wild rose. Prove that the white objects that fill the inside are not seeds. To what part of the apple might the outside coloured part be compared? Give reasons.

7. Make a list of wild fruits attractive by their colour or flesh. Give a note about each, stating what kind of bird or other animal you have observed eating it. Remark on the time of ripening or on any peculiarity of structure.

8. Examine the flesh of the apple and write a short description of it, remarking on taste, smell, consistency, etc.

Then scrape off a small quantity, mix with water and examine under the microscope. Apply blue litmus paper to freshly cut flesh. What conclusion do you draw?

Cut out a cube of the flesh, and having weighed it, dry it in an oven or near the fire, but gently, so that it does not get black. Some time must be allowed for the moisture to be driven off. Weigh again and calculate the percentage of water originally present. If accurate results are desired, a chemical balance should be used for the weighing, and the drying should be done in a special drying chamber, with a temperature of not more than 100° C. How could we ascertain whether all the moisture has been given up?

9. Take an apple stalk that has been pounded in a mortar (or between two stones) and tease a small portion of the crushed material in water in a watch glass. Transfer to slide, examine under microscope, and try and detect the tubes that have conveyed sap to the fruit.

10. Compare the pear with the apple at different ages.

11. Find whether you can get apple pips to sprout.

12. How are shop window apples polished?

CHAPTER III

DISPERSAL OF SEED

Material required.

For demonstration.

Stalks of rose-bay willow-herb with ripe pods. As an introduction to this chapter, a plant growing outside should if possible be observed in the act of scattering its seeds. It could be grown in a school garden for the purpose. A smaller species, the broad smooth-leaved willow-herb, grows everywhere.

Spruce fir cones containing seeds.

Stalks of avens with heads of ripe achenes.

Broom pods.

For individual observation.

The above in sufficient quantity. Two or three cones may supply a whole class with seeds, if their seeds are not already scattered.

Dispersal by Wind. This is an appropriate subject of study for the spacious days of autumn, when the thistledown floats over meadow and moor, or makes swift flights by the breezy cliffs. We are on familiar ground here, for everyone knows about the scattering of seed, even though in these times of many inventions, not everybody has seen the picturesque side of it, when the sower goes forth and with both hands throws the seed about the field. Besides the familiarity that breeds the appearance of knowledge, we may no doubt

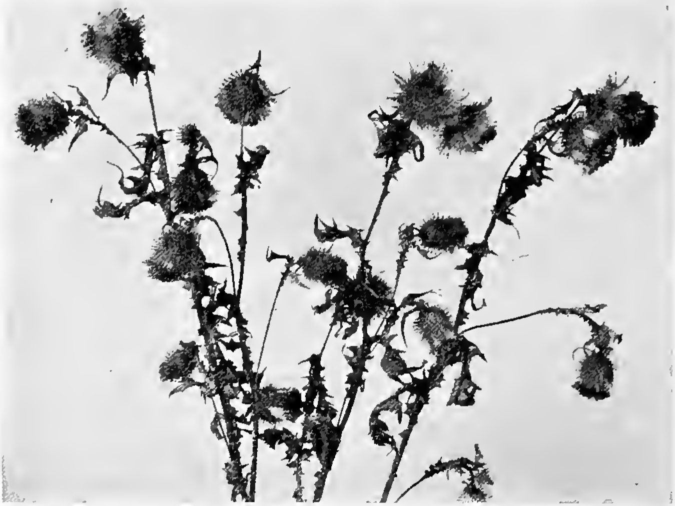

Fig. 3. Thistle in fruiting stage.

have a little experience to work upon, for who has not at some time or other failed to resist the temptation to blow upon the "globe of after arrowlets," and scatter the airy fruits of the dandelion, to which the poet so beautifully refers?

The Willow-herb. One ought, however, to observe the process if possible in some less familiar plant than the thistle or the dandelion. In regard to the willow-herb for example, beautiful and perfect indeed are its arrangements for securing the scattering of its seed. On a day with just enough wind, watch the effect of it on the long bursting pods. Each puff causes the precipitate departure of some of the seeds, which with outspread wings have been straining to be off. Under the influence of a stronger gust, a whole cloud of the fluffy things soars into space, like a flock of little white birds—a pretty sight, apart altogether from the study of the mechanism or from the significance of the operation in the life cycle of the plant. After you have watched the operation as a whole for a few minutes, it would be a good exercise to record in a sentence or two your impression of the scattering of the seeds. This done, examine the pods a little more closely and note some of the more matter-of-fact details. Do the seeds escape one by one or in groups? What is their exact position before leaving the pod? Do they mount high and go far, or do they fall close at hand? All this and much more can very well be observed in the course of a few minutes. Perhaps a pod may be snapshotted, so to speak, in the very act of bursting. Where does the bursting begin?

Pods at all stages may next be gathered and transferred to the class-room for further inspection. By artificially releasing the tips of the four valves of which the pod is composed, we may definitely observe how the seeds have their floats spread ready to catch the wind and how beautifully they were previously arranged in the pod. As to the seed itself we may enquire whether the hairs that help it to float are attached at one end or at various points, and whether the individual hairs are simple or branched. We may note the length and appearance of the individual hair and perhaps ascertain the weight of the seed itself. If a large number of them are weighed together, and the weight thus found divided by the number of seeds weighed, a fairly accurate result may be got. It would be interesting and instructive to form an estimate of the total number of seeds produced by one plant. The total number of pods can easily be got, and by finding the average number of seeds in a pod, the approximate number for the whole plant is arrived at. Recall that each seed, small as it is, contains a tiny willow-herb, and that there are just as many willow-herbs as seeds. When the pods of the parent plant burst, its numerous family is cast upon the world. We note the pods, the seeds, the fluff. We should also realise that we are watching the flight of perhaps ten thousand willow-herbs.

Winged Seeds. With the seed of the willow-herb we may compare that of some species of coniferous tree. The spruce fir will do very well, and a few of its freshly fallen cones may supply as many seeds as are required. Old cones may have lost their seeds. The cone, if ripe, only requires to be shaken and the seeds fall out. If they do not, the scales, whose regular spiral arrangement may be observed in passing, may be removed, when the seeds will be found in pairs on their upper surface. From each hard and rounded seed, there spreads a flat, membranous expansion, not unlike the wing of an insect, and the resemblance is, of course, not altogether a chance one. A simple experiment will prove that, like the insect's appendages, it is of real use. Raise a seed with the wing still attached as high as possible on the butt end of a pointer, suddenly withdraw the support and watch the falling seed. After a descent of a foot or two, too quick for us to observe the manner of it, it acquires the use of its solitary wing, and with greater dignity and more deliberation completes the distance to the floor. The beautiful spiral whirlings do credit to the single wing, and we may now find the rate of the downward movement. Without the wing the fall is so rapid that it is difficult to determine the time taken, and the performance should be repeated till a fairly accurate average is got to compare with the result obtained when the wing was on. The difference, which will be found to be quite appreciable, is a measure of the utility of the wing. The extra time secured gives the wind time to act, while the extent of surface enables it to do so with greater force. The seed is thus dropped at some distance from the parent tree, whose height is another factor in the case. As everyone knows, the cones are mostly at the top.

Hooked Fruits. Another method, perhaps more prosaic, but equally ingenious, is exemplified by such fruits as those of avens. The flowers of this plant are succeeded by a small inconspicuous cluster of seed-vessels, looking absolutely unable to contribute to any result however feeble. At first one does not suspect that the bristles spreading from these seed-vessels on all sides are mechanically as effective as the hairs or the wings that enlist the agency of the wind, but there is nothing like ocular demonstration. Pull one of these heads and, holding it by the stalk, draw it along the sleeve of your jacket. A line of the small fruits will be left behind, and these will have taken a firm hold. What has happened in this case will also happen when in the ordinary course of events any animal brushes past the plant when its fruit is ripe.

Specimens of these fruits should be very carefully examined and then we shall see what the efficacy of the useless looking object depends upon, for it is not only the fact that each fruit is provided with a hook that counts. Held out as it is at some distance from the fruit, it is much more likely to be caught by any passing animal, and the stiffness of this little piece of apparatus and the angle at which it is inclined, all help. Even the brittleness is of service, for this allows the seed-bearing part to be easily broken off and to reach the ground, while the hook, whose service to the plant is now over, may remain clinging to the unconscious scatterer of the fruit.

Owing to the small size of the nutlets of avens, they may be taken for seeds. How can we prove them to be fruits? First by finding seeds inside, and secondly by remarking that they themselves are not contained in anything else, as seeds in plants of this kind always are. If the hooked objects are the seeds, where are the fruits? Their real character is still further fixed if we identify the bristle that ends in the hook as the style.

Other Methods of Dispersal. It must not be supposed that plants whose seeds are unprovided with tufts of hair, or wings, or hooks, will not be dispersed.

Sometimes the means of dispersal are so devoid of specialization, that they may be overlooked. Take for example, foxglove or monkshood. When the capsules of these plants burst, we discover very little in the way of structure for securing the scattering of the seeds. This, however, is accomplished in the simplest possible way. The height of the plants makes them very easily swayed by the wind, and the seeds are then just jerked out. They may fall to the ground at no great distance, but perhaps far enough for all practical purposes.

Then there are the broom pods, which, on a fine dry day at the proper season, make the act of dispersal audible, if not visible, to anyone who takes up his position in a broom thicket and listens. It may not always be convenient to go to the broom thicket, but if the pods are brought home, they may demonstrate their *modus operandi* on the table. The removal of moisture from the pod by dry air causes contraction, and consequent tension along certain lines. Finally the tension resolves itself into a sudden torsion, which shoots the seeds out, and if the operation takes place indoors, it will be possible to measure the distance to which the seeds have been shot. In the case of the broom, although the wind is not the direct agent of dispersal, it contributes to it by helping to bring about desiccation.

It is also necessary to refer in passing to the agency of water, which in some cases is most effective. The cocoanut can travel long distances by sea. Many seeds and fruits that can float are transported by streams.

An altogether different group of conditions occurs in edible fruits, which are very attractive to those animals of one kind or another, by whose agency the seeds are dispersed. Strawberries, cherries and other fruits of a juicy nature are so tempting that nets must be used to protect them and prevent wholesale destruction of the crop. The wild berries, to which the birds of the air have unobstructed access, get their seeds freely and widely scattered by them.

All the methods already mentioned are more or less definite in the details of their working, but over and above all the special mechanisms of dispersal, there must be an enormous amount of scattering by occasional and extraordinary agencies, apart altogether from any adaptation except small size. What a wholesale and indiscriminate transport must take place in some of our wind storms, when clouds of dust and sand are hurried from field to field, from parish to parish, from county to county, even from continent to continent! Along with the sand millions of seeds are sent flying hither and thither whether they have wings or not.

Summary. We are too apt to look upon a seed or a fruit with a special contrivance as something unusual, but seeds which either in themselves or in their coverings are not adapted for dispersal are the exception. There are seeds that fly, seeds that float, seeds that are shot out, seeds that are thrown down, seeds that creep, seeds that ride. They are all up to the same game, all leaving home to set up for themselves in the vegetable world. With so many devices for getting about, it is no wonder that plants of one kind or another cover the earth wherever it is possible for them to grow.

EXERCISES

1. Collect a number of seeds and fruits with visible adaptation for dispersal (omitting fleshy ones at present), and make drawings.

Among suitable ones are thistle, dandelion, willow-herb, avens, goose-grass, sycamore, ash, broom, gorse.

Keep in labelled packets the seeds you wish to sow next spring.

2. Select one (avens for example) for special study. Draw it on a much enlarged scale as large as the paper will allow. Identify all the parts and write a full description, showing in detail how it is fitted to perform its functions.

3. Collect brightly coloured and fleshy fruits. Draw them whole and in section, noting the previous position of the flower. The following are only some of the many that might be chosen—rowan, blackberry (examine the stones carefully), gean (sometimes called wild cherry), raspberry, ivy, grape, melon, plum, pear. Arrange in two or three classes, without regard to method of dispersal, the above and other fleshy fruits.

4. Classify fruits and seeds according to modes of dispersal, and give numerous examples under each division.

5. Set a metronome at 120 so that it ticks half-seconds. Make the experiment described in the foregoing chapter, with the seed from a spruce cone (also ash, sycamore, etc.), and record the result of several trials. Find an average of the time taken for the descent with and without the wing. Try the same with the seed or fruit provided with a float of hairs.

The experiment might also be tried outside to ascertain the effect of the wind.

6. Discuss or classify the services or disservices that wind may render to plants. Refer to many examples.

7. Show in a similar way the relations of animals to plants.

8. Find out how seeds of gorse (=whin=furze) are scattered.

9. Watch the birds eating fruits in garden or hedgerow. What sorts of birds do you see?

10. Describe the interior of a melon. How are the seeds arranged?

11. Examine broom bushes at different times. In what month are the seeds scattered?

12. Keep some fir cones cool and damp. Put others in sunshine or near the fire. How do these circumstances affect the position of the scales?

13. In America the willow-herb is called "fire-weed" because it springs up on ground left bare after fire. Can you find any case of its colonizing bare ground in your neighbourhood? Why does it appear on burnt ground?

14. Can you find any place where spruce fir or Scotch pine is coming up self-sown? If so at what distance and in what direction are the parent trees?

WINTER

CHAPTER IV

THE COCOANUT

Material required.

For demonstration.

Two complete cocoanuts } *to be prepared as*
Three cocoanuts as usually sold } *described below.*

For individual examination.

Acorns, hazelnuts; walnuts, chestnuts, etc.

For this lesson we require a whole cocoanut, a commercial specimen of the "nut," which is really only the core of the foregoing, a cross section of the whole cocoanut, an empty shell cut in two crosswise, and a seed that has been removed whole from its close-fitting cover. With these we are ready to study this remarkable fruit of a remarkable tree.

External Characters. First let us compare the cocoanut with the apple. We soon discover that disparity in size does not prevent the bald, grey nut having, externally at least, some definite points of resemblance to the rosy-cheeked pome. To begin with, both taper to the upper end, the cocoanut more distinctly than the apple. In certain varieties of apple, however, this narrowing is almost as apparent as in the cocoanut, and gives the conical shape so clearly seen in the latter. Then again the five sides of the apple are here represented by three, clearly separated from each other, that run from three knobs surrounding the depression at the upper end, to the three humps that bound the deeper recess at the broad lower end, where the stalk was attached. There are similar knobs and humps round the two depressions on the apple.

Structure. As the apple and the cocoanut resemble each other outwardly in several details, we might expect to find some points of agreement inside as well. From the edible nature of part of the cocoanut many have a knowledge of its interior that may be not altogether scientific. If you were not biased by this, if you had never seen the inside of a cocoanut, but only that of the apple, what structure would you expect to find in cross section? Keeping in mind that instead of the five sides of the apple, the cocoanut (in its complete state) has only three, we might reasonably expect three seed-cavities arranged round the centre and containing two seeds each. We might further expect to find some material corresponding to the flesh of the apple, filling up the space between the skin and the seed-cavities. Nor would our expectation of three cavities be altered if we examined a commercial specimen of the "nut," in other words, the shell, for its surface is longitudinally divided into three segments, and, more than that, the three angles these lines form, where they meet at the sharper end, each contain a small sunk area. By pressing on these scars we find that one of them is soft, and easily make a passage through it to the interior, thereby giving this end of the shell the appearance of a monkey's face. We might infer that the other two scars, if perforated, would lead to two other cavities, but the hardness of each plainly intimates that there is "no road this way," and makes us suspect that there are no cavities for them to lead to. A cross section (or a longitudinal one) makes this certain. Here the analogy of the apple seems to break down. In the five-sided apple we found five cavities. In the three-sided cocoanut we naturally reasoned that there would be three, but find only one. Can we explain the absence of the other two? Can we justify the inconsistent arithmetic of the nut, or is it possible that the cavities are there and that we have failed to see them? Look again. In any case a cursory glance at the cross section convinces us that the apple if misleading in regard to the number of cavities at the centre of the nut, is a true guide in other respects to the structure of the latter. On the outside we have in both cases a thin but well-developed skin, impervious in the fresh state to water. Under the skin of the cocoanut, instead of the sweet flesh of the apple, we have a thick layer of these indigestible strings, whose persistent indestructibility fully accounts for their application to the manufacture of door-mats. In spite of differences of colour, texture and durability, the flesh of the apple corresponds to this fibrous layer in the cocoanut. In scientific language this fact is expressed by saying that the former is homologous with the latter. The ring of shell that separates the thick mass of fibres from the seed is much thicker and harder than the core of an apple, but this does not prevent these two structures being spoken of also as homologous, for they occupy corresponding positions in the respective fruits. With a final glance we may assure ourselves whether or not any ring of dots and lines separates the fibrous layer (or pulp) of the nut into an outer and an inner portion as it does in the apple, and then we turn to the consideration of the single central seed.

The Seed. Instead of six seeds as there might have been, there is only one. If there is lack of numbers there is nothing left to be desired in point of size. The seed is indeed gigantic. Common objects as cocoanuts are in fruiterers' windows and domestically familiar as the fleshy material it encloses is as an ingredient in toffee, the seed itself, except in a broken condition, is not very often seen. This is owing to the strength and accurate fit of the shell. It is possible, however, to release the seed in an uninjured condition from the almost iron grasp of its protecting cover. Lay the nut in an oven or in front of the fire till cracks appear. By taking advantage of these, the shell can be prized off or otherwise removed in pieces. The seed is then exposed to view quite whole. We note its size and egg-like shape and admire the rich brown colour of its smooth and elaborately marked skin. It may be interesting to weigh this bulky cradle of a baby palm. An average weight might be about eleven ounces, and to get an idea of what this means, we have only to compare it with, say, a seed of shepherd's purse, which may weigh about one-seventh of a milligram. The cocoanut seed is over two million times heavier than this. Not that the advantage always lies with the heavier seed. Lightness is in some cases a great help in securing dispersal. An example of this is furnished by the orchis, whose seeds are so light that they can almost float in the air.

Seed in Section. The internal structure of the seed is best seen in a vertical section. Under the brown skin a layer of firm, white flesh bounds the large milk cavity. At one end a small peg-like body is embedded in the flesh, and is also nearly a measure of its thickness. This small object, which differs somewhat in colour from the adjacent flesh, is the young palm. Gently press the point of a pin into it and then raise the pin. Note that the embryo (the young palm) comes with it very easily, being in no way attached to the groove in which it so neatly lies. Had the white flesh been part of the embryo, it would certainly have shown some connection with it. Here, then, apart from the large cavity and the milk it contains, we have three distinct parts in the seed—the skin, the white flesh and the embryo. In the apple the whole of the space enclosed by the double skin is occupied by the embryo, which is nearly as big as the seed. The embryonic palm on the other hand is a mere fraction of the seed that contains it, weighing perhaps about seventy-five milligrams. As the store of food is no part of the embryo, it is known by a different name, being called **endosperm.**

The Embryo. This diminutive plant deserves attention out of proportion to its size, but after we have noted its colour, its smooth, glossy, hairless surface, its plump cylindrical body, with a narrowing about the middle, the flat end which is flush with the outer surface of the endosperm, and the more pointed end directed inwards, there is not very much more to be said, unless we were to examine it in section under the microscope. Division into root, stem and seed-leaf is not so apparent as in the embryo of the apple. Out of this easily overlooked portion of the seed grows the whole palm tree. Like all young things it is a bundle of possibilities, and for it the whole huge nut with its skin, its fibres and its shell exists.

The Lost Cavities. With the embryo our study of the structure of the cocoanut appropriately ends, but we may go back for a moment to discuss one or two questions that have emerged in the course of our examination of it. Where for example are the lost cavities? We expected three and found one. How is this to be accounted for? The answer lies in the nut; in fact, within the thickness of the shell. Firmly imprisoned there are the two lost cavities, insignificant in size certainly, and readily taken for flaws in the shell, but they are there all the same, easily seen in cross section, but of no use whatever now except to furnish us with a clue to the structure of the cocoanut. The explanation is as follows. When the nut was young it contained three cavities of equal size, but only one of the ovules got fertilized. It and the cavity it lay in grew at the expense of the other ovules and cavities, which in an unequal struggle for space, got flattened against the unyielding outside wall, till the condition was arrived at which forms the puzzle of the ripe fruit, where the two cavities and the ovules they originally contained are consigned to the realm of the "might-have-beens."

The Fibrous Layer. From a question of development we turn to one of function. What is the use of the fibrous layer? The outer skin is evidently protective, fitted to prevent water from penetrating to the inner parts of the nut. Still more evidently is the shell by its strength and impervious character fitted to preserve the seed it covers from outside influence, whether animate or inanimate, whether of a solid, liquid or gaseous character. From the point of view of protection the fibrous envelope seems almost unnecessary, and as a matter of fact has another and more unusual rôle to play. We may get an idea of its use if we place the whole fruit in a pail of water and note how well it floats. Cocoanut palms generally grow near the sea in tropical countries, and naturally the ripe fruit often finds itself in the water. In its jacket of fibres it is well able to defy the waves, and under the influence of ocean currents or of the wind, which acts on the large portion of the nut above the water, may sail the sea for many a day, till by some chance, perhaps after a journey of a thousand miles, it is thrown up on some lonely island. Here the well-guarded passenger inside comes out of its shell in a leisurely way, and in due course develops into a full-grown palm. It is in this way that the cocoanut has been so widely distributed over the islands of the Pacific.

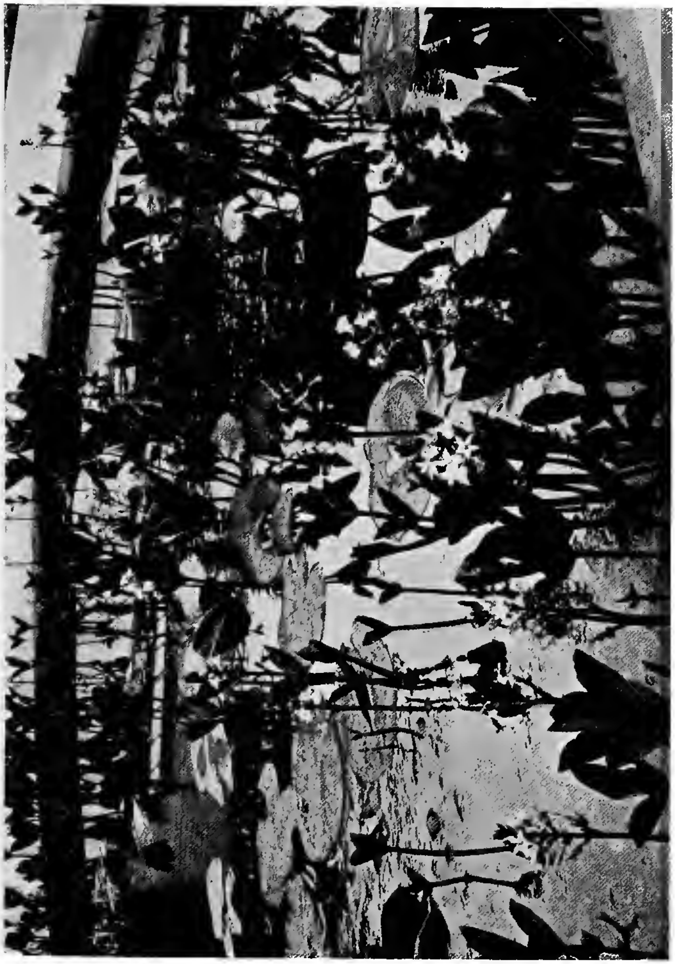

Fig. 4. Water-lilies and buckbean showing relations of plants to water.

EXERCISES

1. Draw (*a*) whole fruit, (*b*) cross section of it, (*c*) end of shell showing scars, (*d*) whole seed, (*e*) vertical section of seed to show embryo in the food store, (*f*) embryo by itself much enlarged.

2. Describe the cocoanut, pointing out the use of all the parts.

3. Immerse whole nut, shell with seed inside it, and seed alone, in water and see if they each float. Account for the floating power of the whole fruit.

4. The acorn, like the cocoanut, is composed of three united carpels and might therefore have had when ripe three cells and six seeds. Usually only one ovule develops and the other five may be found quite small at one end after the shell is peeled off. Compare the acorn with the cocoanut also in other respects.

The acorn and hazelnuts (filberts) are properly spoken of as *nuts.* Give reasons for classing the cocoanut with such fruits as the apple, the plum and the almond instead of with the nuts.

5. Plants differ very much in their relation to water.

Give examples of some or all of the following conditions: (*a*) whole plant floating (free of all attachment), (*b*) root and lower portion of stem fixed under water, (*c*) root and stem entirely below the surface of the water, but with the leaves clear of it, (*d*) floating leaves, (*e*) floating and submerged leaves on same plant, (*f*) flowers under water, (*g*) floating fruits, (*h*) floating seeds. (Consult Figure 4.)

How would you expect plants that grow entirely or partly in the water to differ from ordinary land plants?

6. Are seeds killed by soaking in seawater? Try experiments with several sorts of seeds and for different lengths of time.

7. How do you suppose that the embryo cocoanut gets through the hard shell under natural conditions? Are cocoanuts likely to sprout if sown in gardens in the British Isles?

8. Can you get a cocoanut to sprout? Also try date-stones or other palm seeds. Also try to grow hazel, walnut, Brazil or other nuts, or almonds, grape seeds, or orange-pips. Are acorns easier to manage?

9. Compare the cocoanut and the chestnut.

CHAPTER V

CROCUS CORMS

Material required.

For individual examination.

Fifty (or more) corms of good quality with large shoots and in fresh condition (for class of 24).

Crocuses produce seeds, but nobody thinks of sowing them. In order to get a show of crocuses in spring, we plant in autumn the small objects that form the subject of this lesson. They may be classed with bulbs, but are accurately spoken of as **corms**. They will be found to be rather more instructive than they look, especially when we come to examine the upper and fresher looking parts. We shall begin with a general examination of the corm as sold by a seedsman.

Shape. An india-rubber ball rather less than an inch in diameter, if slightly compressed between finger and thumb, represents fairly accurately the size and shape of a mature corm. Other comparisons may be made after removal of the loose brown covers which somewhat obscure the outline.

The Brown Tunics. We begin our examination by taking off the outermost and largest of these tunics. It is attached along a wavy and approximately circular line running round the corm, not far from the depression at its lower end. From this line the tunic follows the body of the corm upwards, clinging rather loosely and bringing together its ragged margin round the two or

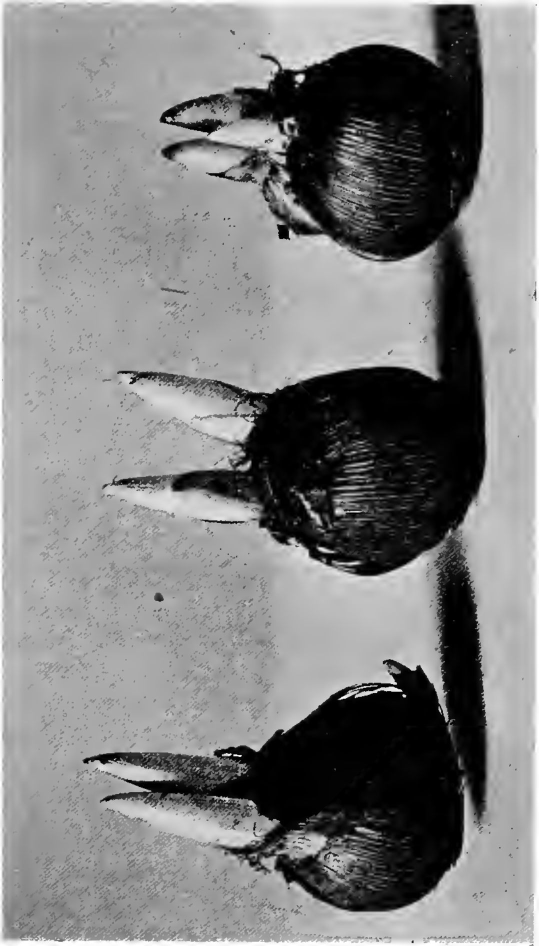

Fig. 5. Crocus corms.

three light-coloured shoots which, arising in a cluster from the hollow at the top, resemble nothing so much as a collection of small tusks. Alongside of the shoots with their clean-cut outline, firm setting and compact structure, the tunic looks insignificant enough. It is so easily detached from the corm, so easily torn along the parallel lines that mark its surface, and so withered looking, that one is not impressed with its importance as an integral part of the corm. Before endeavouring to find any evidence of the real nature of the tunic or any justification for its existence, we may take off the remaining tunics, which are fixed along lines higher up than the first. The points in which all the tunics agree and differ may be enumerated; and, of course, one of the most obvious resemblances is the presence of the parallel lines that run from the base to the upper edge of each.

Homology of the Tunics. Having observed the facts, let us draw some conclusions with regard to the nature of the tunics. Can we settle their homology? That is, can we say what type of organ they represent? Are they modified roots, modified stems or modified leaves? The well-developed parallel veins of course suggest the leaf type of organ, and so do both the thinness of the tunics and their tendency to fade and fall off. This is nearly sufficient proof, but take one fact more. Just above the line of attachment of one of them may possibly be found a shoot much smaller than those at the top. The shoot being nothing but a bud, we have no difficulty in identifying the tunic as the leaf in whose axil this bud has arisen.

Leaves then they are, but, of course, dead leaves, and of little further import in the life of the plant.

As long as they remain where they are, they may help to protect what is underneath from mechanical injury, and are possibly of other service as well. If this is their use when they are dead, one naturally wonders what use they were when alive, and what they were then like. Both these questions will be cleared up as we proceed with the examination of the corm, now denuded of its tunics.

The Corm without its Tunics. The light-coloured object now laid bare is very firm and smooth. The surface, however, is freely, though not deeply, pitted and has numerous brown wart-like marks dotted over it. By scraping it a delicate skin may be detached.

Homology of the Body of the Corm. If you have discovered that the brown tunics are really leaves in disguise, there should be little difficulty in proving that the body of the corm is a modified stem. Its appearance certainly is at variance with our ordinary conception of a stem, but as it bears both leaves and buds, it cannot well be anything else.

Its Function. In search of some reason for the peculiar shape of the corm, we make a longitudinal section, and find that internally it consists almost entirely of a white material, apparently homogeneous. This is slightly spongy, but is firm enough to cut well, and, if the corm is fairly dry, can be scraped off as a white powder. The application of the iodine test (see Exercise 11, p. 60) at once proves the white substance to be starch, which we readily infer to be a reserve store. The particular part of a plant in which a store is accumulated is in need, not of length or suppleness, or even of strength, as the ordinary tree stem is, but of capacity; and for accommodating as much material as possible within easy reach, no better shape could be found than the sphere, to which the body of the corm has approximated as nearly as circumstances permitted.

But the corm is not so very unlike a stem after all. Does it not support leaves, shoots and, ultimately, flowers? More than that, it acts to a certain extent as

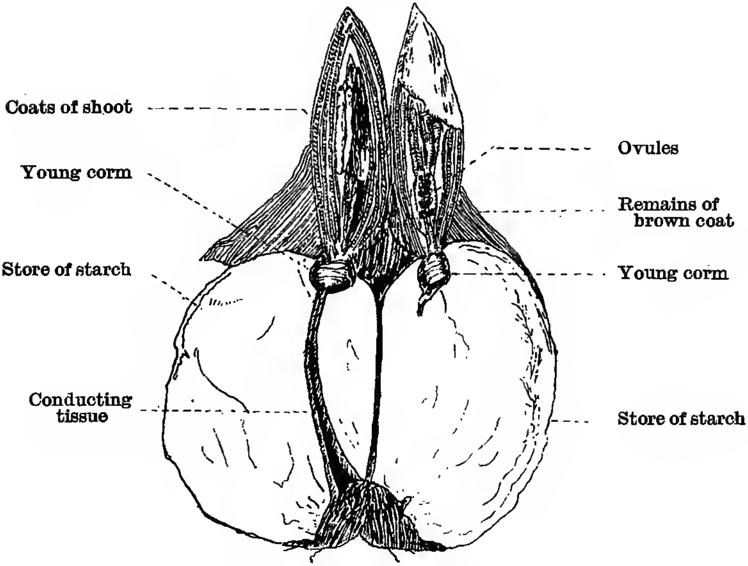

Fig. 6. Vertical section of crocus corm.
(From a class drawing.)

a conducting medium. Yellow markings of a streaky nature, which may be seen on the white ground of the section, are really bundles of vessels running to the bases of the shoots. An examination of the details of the structure of the body of the corm emphasizes the fact that form is an expression as well as a result of function.

The Shoots. The shoots at the top of the corm, as can be well seen in a vertical section, are neatly and firmly placed in small pits in the upper depression, and some care has to be taken if they are to be removed intact. Before beginning to examine the shoots, can you guess what is likely to be inside them? As everybody knows, the crocus corm produces flowers. Are the flowers in the shoots *now*? Is it possible to tell how many flowers would have been produced if the corm had been planted? Where will the new corms come from? With questions like these in view, we may turn to one of the shoots for information. The shoot is lanceolate in vertical outline, tapering from below the middle to the two ends, of which the lower is the broader.

The Coats. The outer portion, which is light-coloured, smooth, hairless and marked with parallel veins, can be peeled off, and is seen to form a coat enveloping the greater part of the shoot. Its line of attachment is at the lower end. Another coat of a similar nature comes below the first, a third below the second, and so on. As coat after coat comes off, one's surprise grows at the complete and manifold protection which the outer portions of the shoot afford the inner. Taking off the coats seriatim and writing a short description of each as it is removed, forms an excellent exercise in observation and description. After all has been described, the points of resemblance and difference may be summarised in a sentence or two.

Homology of the Coats. After such an exercise there will be as little difficulty in referring the coats to the leaf type, as in perceiving that their function is a protective one, which they perform in a very efficient manner. Individually the coats are not strong, but one fits so closely on the top of another that, as a whole, they constitute a substantial wall of defence for the important organs they shelter.

The Shoot without its Coats. When all the coats have been taken off down to the very base, we see much more clearly the shape of the small globular body to which they were attached. From its upper end and within the cone of coats, rises a clump of three or more club-shaped objects with yellow contents showing through the delicate sheath, which looks like a wrapping of tissue paper round each. Encircling these is a ring of small pale-yellow strap-shaped organs, which complete the tale of the parts of the shoot.

The New Corm. The attachment of all these organs of the leaf type and its own spherical shape, are sufficient to lead us to the correct conclusion that the small body at the base of the shoot is really the new corm. It is evidently a stem-like structure, and as it springs from the old corm, it can be nothing else but a branch of it. With the discovery of the new corm, we discover too that the coats of the shoots, now white and soft, are destined to turn into the brown tunics which in their withered age will remain the faithful protectors of the firm old corm, whose tender youth they guard so well. Even already the white coats have got the extra glossiness on their inner side, which they retain to the end of their useful existence.

The Leaves. The pale-yellow organs rising from the top of the young corm and lying next to the coats, we may at once accept as leaves, owing to their likeness to these organs of the crocus as we know them at a later stage, when exposure to light has made them green, and a period of vigorous growth has made them long.

The Flowers. Last but not least in size or importance come the club-shaped parts. Under their sheath is a flower, which we readily identify, though it may take a little time to make out all the details of its structure. The upper portion which is of a bright orange colour attracts attention first, and may rashly be called the **perianth**[1], but we are driven to a different

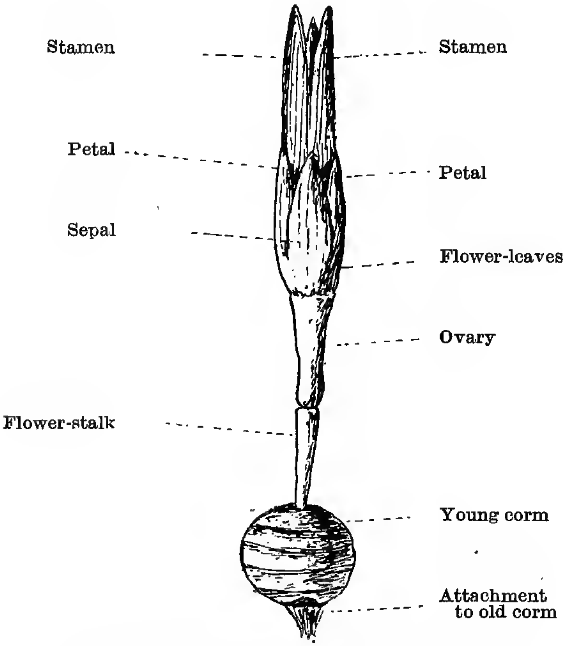

Fig. 7. Single flower from shoot of crocus corm. (From a class drawing.)

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[1] "Perianth" includes the calyx and the corolla. Sepals and petals are perianth leaves

opinion by the discovery of a double circle of flat organs of a lighter colour. These are placed lower down and to the outside of everything else (three of them being outside the other three) and are shaped like an inverted heart and most delicately veined. These must be the flower-leaves. At present they are dwarfed by the larger organs they surround, which, however, they will soon overreach and ultimately envelop.

The remaining parts of the flower will be most easily identified if we make a longitudinal section. Above a constriction which marks off the flower proper from its stalk there will be seen a slightly swollen portion. In this some rows of very small rounded objects will after a little looking be detected. These must not be called seeds. At the present stage in the flower's development it is impossible for them to be anything more than ovules. The cavity in which they lie must, of course, be the ovary; the rod-like body arising from it is the style, and the three fringed fan-shaped organs which spread from its uppermost end are the stigmas. Having identified the perianth and the pistil in all its parts (ovary, style and stigma), we readily surmise that the three large orange-coloured bodies, in spite of their disproportionate size, are stamens, and a closer examination will confirm us in this conjecture.

The Purpose of the Corm. It will thus be seen that before crocus corms are planted, they contain everything that will afterwards come out of them. Their state of preparedness for the future is indeed remarkable. The flower is already complete in all its parts. The stigmas are fully formed and need only to grow bigger. The style has only to lengthen, and in the ovary the ovules are already arranged in neatly set rows. The pollen is even now in the making in the bright yellow heads of the stamens which are at present quite out of proportion to the inconspicuous flower-leaves, which by and by will hide them in the brilliance of their floral vase. The whole thing is like a machine ready to be set in motion. Every part is in its place.

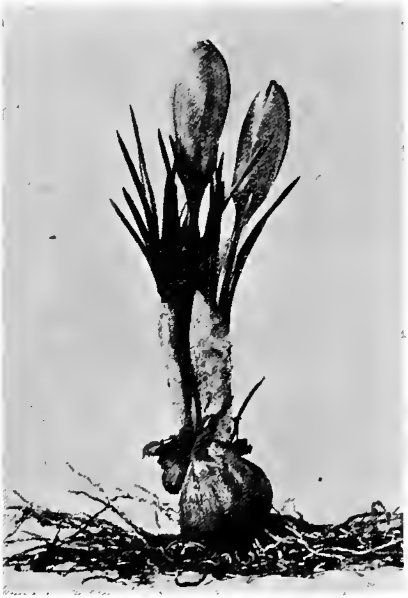

Fig. 8. Crocus in flower.

Even the fuel is on the premises in full store. Nothing remains but to set agoing the flameless fire. This will in due course be done by the genial influences of spring, when fullness of preparation will find fruition in the birth of young crocuses in the depth of a flower cup of dazzling yellow, of royal purple, or of stainless white.

EXERCISES

1. Make drawings of:
   - (*a*) whole corm.
   - (*b*) longitudinal section of corm.
   - (*c*) a shoot with its coats removed.
   - (*d*) a single flower with sheath removed, but with young corm attached below.
   - (*e*) a single flower with one stamen or all removed so as to show the stigmas.
   - (*f*) section of the ovary.

All except (*a*) and (*b*) should be considerably enlarged. State the scale in each case.

2. Repeat (*d*) of the last question to the scale of 6 or 7, showing all details and naming every part.

3. Write a general description of the whole corm.

4. Give a detailed account of a single shoot in not less than two or three pages.

5. Write a few lines about each item in the following exercise:
   - (*a*) Prove that the young corm is a branch.
   - (*b*) How does the flower in the shoot differ from a flower in full bloom?
   - (*c*) Describe the white material that forms the bulk of the corm. How and when is it of use?
   - (*d*) Enumerate the various kinds of leaf to be found attached to the corm or its shoots.
   - (*e*) How do you know they are leaves? How is each kind of use?

6. Examine an onion, a daffodil or a tulip bulb and show either by drawings or in writing how it differs from a crocus corm.

7. Examine under the microscope:
   - (*a*) Starch from the corm mounted in water. Stain while under examination by putting a drop of

iodine at the edge of the cover glass and drawing it through by applying a small piece of blotting-paper at the opposite side.

(*b*) A piece of skin peeled from one of the coats of the shoot.

(*c*) The contents of anther of stamen squeezed out on the slide and mounted in water.

(*d*) Section of ovary either longitudinal or transverse.

Give drawings or descriptions, or both.

8. What kinds of insects visit crocus flowers?

9. Find out by one or two simple experiments whether it is light or heat that causes a crocus to open. It is convenient to have some crocuses growing in pots. By placing a plant (after some of the flowers have opened under ordinary conditions) in a dark cupboard or box at a fairly high temperature, and another in a sunny but cold position, some conclusions may be arrived at.

10. The experiment might be tried of growing crocuses in pots and keeping them in the dark all the time. Describe result.

11. Scrape off with a knife some of the white substance from the cut surface of a corm and then shake it up with water in a test tube. Add a drop or two of iodine solution. If the solution turns blue, starch is present. Heat the solution and note any change. Examine again after cooling.

12. Test some or all of the following for starch:

acorn.
flesh of apple.
potato.
turnip.
rice.
pea.
bean.

The material to be examined should be scraped from a cut surface. The very hard specimens must first be soaked for some hours. Say how and when the starch, if present, will be used.

13. Ask the seedsman whether he keeps "autumn crocus."

14. Watch a place where crocuses grow and record what can be seen in different months of the year, December, January, February, March, April, May, June, etc.

15. Dig up some crocuses. Wash them clean of soil. Sort them and arrange if you can in what seems to be age order. Draw crocuses of different ages.

16. Use a seedsman's illustrated catalogue containing descriptions of different varieties of crocus flower. Name the flowers provided and give reasons for your answers.

17. Draw and describe the seeds of the crocus.

CHAPTER VI

A CABBAGE

Material required.

For demonstration.

A large smooth-leaved cabbage (without removal of root or outer leaves) to be taken to pieces as described in this chapter.

Another of the same to be shown in vertical section.

For individual examination.

Brussels-sprouts.

Selection of Specimen. An ordinary smooth-leaved cabbage is best for this lesson. As the greengrocer from whom we order it a few days in advance cannot be expected to divine that we intend to divert our purchase from the usually inevitable pot and extract mental pabulum from it instead, he would naturally deliver it docked of some of its outer leaves and minus the root. He is therefore instructed to see that it is sent complete, and further, that it is one with a large and firm heart. Better still, choose your own cabbage at the market gardener's.

Provided with such a specimen, we may proceed to examine it, well assured that in spite of our familiarity with it as a cooked dish, we have not exhausted the store of information that may be derived from it. In fact it is surprising how little one knows about what one eats so often. Can you for example answer these questions? Is the cabbage composed entirely of leaves? Are they arranged in any particular way? What do you expect to find at the centre of the heart—flowers, seeds, an empty space or a solid lump? Are there any buds or branches in a cabbage?

The Stem. Before proceeding to remove the leaves and find the answer to some of these questions, and to settle perhaps whether the leaves come nearer 50, 100 or 200, or any other doubtful point, we may take a glance at the stem, whose strength, considering that the plant has been growing for less than a year, is decidedly remarkable. Perhaps not less so is the increase in diameter which begins a few inches above the root and is accompanied of course by a great increase of surface. The latter is worthy of inspection, for the obvious roughness will be found to be due to arrangements of a definite and regular character. The greatest amount of space is taken up by mouth-shaped or perhaps lip-shaped areas, clearly outlined by their neatly raised edges and distinguished by colour from the smooth, green and narrow bands that divide them from one another. There may not be much difficulty in proving that these are leaf-scars and that the green portions represent the surface of the stem. In addition to other evidence the presence of a bud above each scar places the matter beyond doubt. It may not be so easy to discover the exact plan upon which they are arranged, but we may at least explain the curving line of dots that runs across the scar. Take note of the way the latter comes to a fine point at the two ends, which may be as much as two or three inches apart. The cabbage is largely a collection of leaves, as is evident in its upper portion, but here lower down, where they have disappeared, the collective impress of their areas of previous attachment is so extensive that very little of the stem's own proper surface is visible.

Parts of a Cabbage. The cabbage may roughly be divided into three portions, the root, the portion of the stem from which the leaves have fallen, and the heavy upper portion which, externally at least, shows no sign of stem at all.

The Head. To the examination of the last, which is more especially the subject of this lesson, we now proceed and may appropriately commence by noting its large size, which conveys a general impression of top-heaviness. We may corroborate this by an appeal to a balance, which will give us the weight of the whole cabbage, and also of the upper portion by itself (though for the sake of convenience in handling it, it is not desirable to cut off more than the root at this stage).

The Leaves. And now for the leaves. How many are there? Are they all the same? If not, how do they differ? How are they fixed? What is the plan of their arrangement, if there is any? What will be left when the last leaf is removed? With these and possibly other suggested enquiries, we proceed to pull off the leaves, beginning with the lowest, which will actually be uppermost if for convenience we turn the cabbage upside down on the table. We note its great size of blade, the want of stalk, the fine green colour, the wavy outline, the broad veins and solid weight, and perhaps the effect of time as shown by decay of colour at the margins, and the inroads that insect life and weather have made on the continuity of its substance. Then comes the second exactly like the first. We take it off and lay it alongside, and so with the third and all the rest of the outer spreading leaves, of which we have now a long row on the table, where we can plainly see a gradual diminution in size and a fading into lighter shades of the proverbial green of the cabbage, so well seen in the leaves first taken off. Our row of leaves is now a yard or two long, but though colour and size are going, there is as yet no sign that the supply of leaves is at an end. All the spreading ones are off, but the heart of the cabbage still remains a solid mass of others, closely packed. We peel them off, adding to the length of the row on the table, and gradually subtracting from the size of the heart. Paler and paler they get till the healthy green is represented by a sickly white. Smaller and smaller too they grow till they are just about one-half or one-third the size we started with. With change of colour and size there is also a change of shape, for the leaves are now basin-shaped or shell-shaped instead of being nearly flat, and there will be no harm in pausing for a moment and filling one with water to find its capacity and to demonstrate its waterproof character. Our line of leaves is now so long that no ordinary table will be able to accommodate its further extension. So we turn and go backwards. It should be noted that as we have removed leaf after leaf, more and more of the stem has been exposed to view, and every leaf is a little higher up than its predecessor. We conclude that still more of the stem remains hidden by the overlapping leaves not yet removed. These we take off as quickly as possible, noting still another change in colour from the white to a distinct yellow. Perhaps still more noticeable is the continued decrease in size. We might suppose we have nearly finished, but still they come. As yet no flower or seed-vessel has appeared, only leaves. Some more may remain, but we stop with one about one-eighth of an inch in length. Now we survey the display of about 80 leaves beginning with the largest and ending with the smallest, which, when set alongside the first, looks almost comically microscopic. With the aid of a chemical balance, we discover that one of the smallest leaves weighs about 15 milligrams, whereas the first one weighs about 15,000 milligrams, that is, 1000 times as much as the smallest—a mighty difference, yet the biggest one was once as light and as small as the smallest. The extraordinary change has been brought about by the process of growth inside the leaf, and in the course of its development it has passed through all the stages in the varied line.

It is natural, of course, to ask why the inner leaves are yellow and easy to explain that the paleness has been caused by want of light. The lack of size is due to the fact that the small leaves are younger than the large ones and therefore have not had time to grow.

Relation of Leaves to Stem. It must also be pointed out that the larger leaves in their earliest stages were at the tip of the stem which as it increases in length gradually gets beyond the leaves it has formed and goes on to make new ones in front, though it does not neglect the older ones, which by their vital connection with the main axis are supplied with the materials which make their extraordinary growth possible. It is very important to observe that the heart of the cabbage, though largely formed of leaves, has the stem running right into it and that all the leaves, large and small alike, young and old, are attached to it.

The Cabbage as a Bud. Now we ask what part of an ordinary tree most resembles a cabbage or rather the heart of a cabbage. Let not difference in size blind us to resemblance in structure. What part of a tree, then, consists of leaves packed closely together, fixed to an axis which runs up the middle of the mass in a position to supply every leaf with materials for future expansion and growth? Surely no one can suggest any other part than the bud. It is true that the buds most generally observed are provided with an external covering of hard scales, but this is a comparatively unimportant extra. In all essential points of structure, the cabbage and other buds agree, consisting as they do of the growing point of a stem or branch covered by young leaves, packed in such a way that the older ones enclose the smaller and younger ones. Plants are too often studied in fragments—leaves apart from the stem, the parts of the flower simply as organs without reference to their function, and without relation to the flower as a whole. Buds in particular are overlooked, partly no doubt owing to their small size, but as on them in the case of the higher forms in the vegetable kingdom all extension of the stem is accomplished, as well as all floral development, they really deserve special attention. In a bud too we do not study an isolated organ, or an isolated stage of an organ. Here we have the relation of leaf to stem and stem to leaf, as well as a series of stages in the development of the leaf itself. From few plants can we get more easily such a good idea of the essential details of bud structure than from the cabbage.

EXERCISES

1. Draw a vertical section of a cabbage.

2. Give a general description of a whole cabbage, paying special attention to the arrangement of its parts.

3. Procure a good specimen of brussels-sprouts and show that in spite of its totally different appearance, it is really of similar structure to the cabbage. Count the spirals formed by the sprouts, first those running from left to right, and second, those running from right to left. Take the smaller number you find as numerator and the sum of the two numbers as denominator, and see if the resulting fraction is identical with any of the series: $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{5}{8}$, $\frac{8}{13}$, $\frac{13}{21}$, $\frac{21}{34}$.

4. How does a cabbage differ from an ordinary winter bud, such as that of a horse-chestnut tree? How does it resemble such buds?

5. Describe one of the fully developed spreading leaves of a cabbage. What are the characters of its surface? Some of these can be discovered by drawing the finger along it.

6. Tear off the skin from the surface of a leaf. Feel it, pull it gently, lay it on print, leave it exposed to the air, and you will discover some of its qualities. Give an account of them.

7. Answer briefly the following questions:

- (*a*) Why are the leaves of the centre smaller than those on the outside of the cabbage?
- (*b*) Why do the leaves at the foot of the stem fall off first?
- (*c*) Why are some of the earliest leaves of the cabbage smaller than those that appear on the outside of the fully formed cabbage?
- (*d*) What advantages come from the younger leaves covering the point of the stem?

(*e*) Why are no seeds to be found in the heart of the cabbage?

(*f*) How can the leaves in the centre grow, when unable to manufacture food owing to lack of light?

8. Give examples of plants in which the following parts are edible:

Root.	Fruit (as a vegetable).
Stem.	Seed.
Leaves.	Bracts.
Leaf-stalk.	Buds.
Inflorescence.	Seedling (or most of it).

9. Make microscopic examination of:

(*a*) The skin of the leaf.

(*b*) Vessels from the veins of the leaf.

(*c*) The green substance which composes the interior of the leaf. Scrape some of it off after the skin has been removed.

10. Soak a portion of a green leaf for a night in methylated spirit and see if the green colour is destroyed or removed. Subject yellow leaves from the centre of the cabbage to similar treatment and note result.

Can the colours of leaves or petals be extracted by boiling in ordinary water?

Do yellow leaves become green on exposure to the sun?

11. Describe a cabbage that has run to seed.

12. Obtain some cabbage seedlings from a gardener and plant them out in your own garden.

13. Also sow some cabbage seed.

14. Draw a cabbage flower. What other flowers are like it in shape?

15. Boil some purple cabbage leaves in water. Filter or strain the solution. What colour is it? Does the colour change on addition of (*a*) vinegar, (*b*) orange juice, (*c*) soap, (*d*) washing soda? If so, what is the change in each case?

16. What is the difference between (*a*) broccoli, (*b*) cauliflower, (*c*) cabbage, (*d*) savoy, (*e*) kale?

SPRING

CHAPTER VII

CAUSES OF GERMINATION

Material and apparatus required.

For demonstration.

One ounce of white mustard seed.
Five 4-inch pots.
Dry soil to fill one pot.
Potting soil in ordinary condition to fill the other four.
One glass jar.
One plate or saucer.
Cotton-wool or small piece of flannel or a little sawdust.
Bell-jars or glass shades to cover the separate experiments. } *not indispensable*
Two thermometers. } *not indispensable*

One of the commonest ways of getting new plants is to sow seed. In the soil a seed begins to sprout, a root is sent out, fresh green leaves appear above the surface and we say the seed has **germinated.** Under the name of **germination** we include the first stages of the wonderful development of a complete new plant from the simple embryo enclosed in the seed.

It is not difficult to say with what season germination is specially associated. Summer is the time of flowers, autumn of fruit, winter of resting seeds and closed buds, and spring of seedlings and shoots. Spring is above all a season of awakening. It is the morning of the year when the sun comes back from his visit to southern climes, bringing light and heat once more. The butterfly comes out of its chrysalis, eggs are hatched in the nest, tadpoles wriggle in the pool, buds break into green leaves, and the sleeping plant inside the seed answers like the rest the call of spring, comes out into the sun and vigorously grows.

In our own country, where the weather is so variable at all times, this wonderful renewal of activity, both in the animal and vegetable world, does not produce the same ocular effect as in some other regions, where the seasons are more clearly marked off from one another. In the steppes for example, white sheeted winter takes a definite departure at the proper time and almost suddenly it is spring. The seeds germinate, and as if at a magic touch the world is green. In our own land too with its more gradual transitions, germination is specially connected with spring and seedlings shoot up on every side, though we hardly notice them. How many must there be in a single garden, in a field, in a parish, in a county, in a country, in a continent, in the northern hemisphere! Germination is in the air. Unnumbered millions of baby plants are awakening up to active growth about the same time. What a bursting of cradles, what a turning down of roots, what a shooting up of stems, what a spreading out of leaves! What is the cause of all this extraordinary activity? As germination takes place in spring and not in winter, we may conclude that some cause is operative in the former season and not in the latter. Now the chief difference between the two seasons lies in the amount of light and heat received at the surface of the earth. If germination is due to either of these causes, or to them both combined, it is in that case controlled by the motion of the earth round the sun. But if the laws that govern the planets have anything to do with the matter, can we expect to find out what it is that makes a seed sprout, from a few simple experiments done indoors? We shall see.

Perhaps it may be suggested that the cause of germination lies in the seed itself. When it was ripened chemical processes may have been set agoing which, without any help from outside, bring about germination after so much time has elapsed. A little reflection will show that this cannot be the explanation, for seeds may be kept for any length of time in a dry place without germination taking place. It is evident that some outside cause is at work. Here we must remember that a cause out of touch with the thing to be acted on cannot be operative. Causes of germination therefore must be looked for among the substances that are close to the seed or among the influences that act directly on it. Some of these are:

Soil	(solid).
Water	(liquid).
Air	(gaseous).
Light	(forms of energy).
Heat	

Let us see if we can arrange a few experiments to show which of these is really responsible for bringing the baby plant out of its shell, for making it, so to speak, answer the call of spring. We cannot apply the causes one by one; otherwise, taking five sets of seed, we might give the first soil, the second water and so on. If any of the seeds germinated, we should at once know which was the cause. Difficulties, however, crop up. It is easy to deprive a plant of light, but not so easy to take away all heat. Then again, germination might be due to a combination of causes and not to one cause alone, in which case none of our five sets would show any signs of growth at all, and the result would be entirely negative.

So we must arrange the experiments on a different plan, withdrawing one cause at a time. The one set will get no water, another no soil, and so on. Then for example if the set without soil germinates, it is perfectly clear that soil is not the cause of germination, nor part of the cause we are in search of. With these preliminary remarks, we are ready for the experiments themselves. The material and apparatus required include mustard seed, water, potting soil, pots, bell-jars, a cylindrical jar, one or two plates and a few thermometers.

The first set of seeds is sown under ordinary conditions, the seeds being sprinkled on the surface. It is not necessary to put soil on the top of them. To prevent drying up by the heat of the room, it is advisable to cover the whole thing with a bell-jar, ventilation being secured by removal of the stopper. A second set, similarly arranged, is deprived of light by being placed in a light-tight cupboard. A third set is deprived of moisture by being sown in soil that has been thoroughly dried. Any influence that soil may have is removed by placing the seeds on flannel, cotton-wool or sawdust resting on a plate with a little water. Then comes the problem of a set without air. It is not very convenient to use the air pump and it will be no good to put the seed in a bottle quite full of water and tightly corked, for at the same time as you cork out the air, you also cork it in, there being two or three per cent. of air in water. A simple method will suffice. After some water has been boiled to remove the air, and allowed to cool in a cylindrical jar, drop the seeds in. They will sink to the bottom and the small bubbles of air they take down with them may be afterwards set free by careful stirring. Soil may be dropped in before the seeds. All the foregoing sets should be kept at the ordinary temperature of a room. A sixth set sown in the usual way may be placed outside, and, if the experiment is made early in the year, the average temperature to which it is exposed may not be much above the freezing point. Readings from a thermometer placed alongside should be taken several times a day. If a hothouse is available, it will be instructive to place a seventh set there, exposed to a temperature of 70° or 80° Fahrenheit. Here is a tabular view of these arrangements:

SET 1	soil	water	air	light	av. temp.
SET 2	soil	water	air	—	av. temp.
SET 3	soil	—	air	light	av. temp.
SET 4	—	water	air	light	av. temp.
SET 5	soil	water	—	light	av. temp.
SET 6	soil	water	air	light	low temp.
SET 7	soil	water	air	light	high temp.

As mustard seed germinates very quickly, results may begin to show themselves in one or two days, and from then onwards progress may be noted daily. It is also satisfactory to leave the experiments alone for a week or ten days. At the end of that time it will be possible to arrive at definite conclusions, and perhaps the results may appear more striking than if an inspection is made every day. In any case full notes should be made recording not only germination or its absence in each case, but also whatever else seems worthy of mention.

Results. About the seeds in the dry soil nothing of course can be said, except that they have not germinated. They are as they were. Water evidently is an essential condition, for judging by set 1 these seeds would certainly have germinated had water been supplied. The seeds under water have fared little better than the dry ones. Swelled, of course, they are, but beyond that there is no sign of growth, and so air is another *sine quâ non*. About the seeds that have been in the dark quite a different tale is to be told. The tall, delicate, light-coloured stems growing perfectly straight up, are a contrast to the sturdier, darker stems of those that have been grown under ordinary conditions, when each seedling, in addition to these other characters, shows a distinct slope towards the source of light. Not less remarkable is the difference in the leaves which in the former case are yellow, small, and not well spread out, while in the latter they are of a dark, healthy green, larger, and spread out flat. In spite of all these differences, the main fact is that the absence of light has not prevented germination. At the same time it is clear that seedlings grown in the dark are neither normal nor healthy. As the seeds sown on flannel have germinated, we conclude that soil as well as light may be dispensed with in the early stages of a plant's development. And now we consider the fact of temperature, which is evidently very potent, for the seeds kept at just above freezing point show very little progress, while those under the influence of ordinary temperature have done well, though far outstripped by those with extra heat.

Essential Conditions. We may now sum up and say that the only external essentials are heat, air and water. Given these, the seed will make a start. Here we see the importance of the sun. The air we have always and everywhere and generally water even in winter, but in the absence of sufficient heat nothing takes place. Only when the sun with the revolving year warms the earth again, do the sleeping embryos waken up to active life.

It may further be noted not only that heat is necessary for germination, but also that it has an extraordinary effect on the rate of growth that follows. When a box of mustard seed that has been in the hothouse at a temperature of about 80° Fahrenheit for, say, a fortnight, is compared with another box that has been for the same period just above freezing point, the difference is perfectly astonishing. The former box has seedlings vigorous and green, and perhaps 3″ in height. The seeds in the other box show some signs of germination, but have made no progress beyond the first stage. Similar though not so striking results would be obtained if one set were kept at 60° and another at 40°. From this one can readily imagine the disastrous effect that a prolonged spell of cold weather would have on the crops of the country. The effect of light, which has already been dealt with, is in some ways even more remarkable, for it affects the length of the stem, the size and colour of the leaves, and even the direction in which the plant grows. In fact a plant grown in the dark is hardly recognisable. It is not even necessary to arrange an experiment to be assured of the healthful effect of light. We may infer this from the weak and lanky plants to be found growing in too much shadow, or from the sickly specimens in ill-lighted rooms. What these miserable things need is not more water or more heat, but a flood of sunlight. That will put new vigour in them and impart to their leaves the bright green that indicates vegetative health.

Just as crops may suffer from a cold summer, so they may suffer from a dull one. A summer may be hot and dull, or it may be cold and bright, but neither alternative suits the crops. What they need (always supposing that the ground does not get too dry) is plenty of heat and plenty of bright sunlight.

Influence of the Sun. Throughout the whole life of a plant, the sun is the dominant factor. Owing to it leaves are green, blossoms open, fruit ripens. Equally important is it at the very first stages, for its warm touch in spring sets the living machine in motion. The sun is paramount. It warms the earth and the winds blow. Through it therefore comes the rain that gives rise to rivers and makes vegetation possible. If it were not for the light of the sun, the world would not be green. Without this colour there would be an end of all those organic compounds on which life (both vegetable and animal) depends. Life indeed would disappear. It is instructive to see this dependence on the distant luminary, not only in the broad facts of physical manifestation, but also in the circumscribed details of insignificant individual existence. Whispered by the zephyrs, proclaimed by the roaring gale, this chorus of creation is the truth vouched for by the humblest single plant. Place a grain of mustard seed on a wet surface, and let it germinate. The tiny seedling tells the same old tale. It is the sun that makes the world go round.

EXERCISES

1. Make drawings of mustard seedlings at various stages, and for the sake of comparison draw alongside of them seedlings of any weeds or other plants you may find in cultivated ground.

2. Write a full description of a seedling that has got its third and fourth leaves unfolded. Note particularly where there are buds and hairs. If the root hairs are visible, they should be fully dealt with.

3. Make the experiments described in the foregoing chapter and give an account of the results.

4. Grow some mustard on sand or potting soil and keep a diary of the changes as they occur. For the first ten days or fortnight one entry or even two may be made every day. Thereafter progress may be noted every two or three days till the flower or fruit appears. In this way a very complete idea of the development of the plant can be got.

5. Procure a box about 18 inches long, about 5 inches high and the same in breadth. It should be divided internally into three compartments and each of these should have a window to the front, one of ordinary glass, one of blue and one of yellow. The back should be hinged to fold down. Sow mustard seed in each compartment and place in full light. Photographic quarter-plate developing trays may be used instead of pots. When the seedlings are a few inches high, carefully compare the three sets and draw conclusions as to the effect of light.

6. Sow mustard seed pretty thickly in a box or pot. After the seedlings are about an inch in height, take out half a dozen of them and plant each one separately in a small pot or all in the same box several inches from each other. If the latter make better progress than those left to grow where they were sown, give more than one reason for the result.

7. Plant a turnip in a flower pot and leave it to grow (with occasional watering) in an absolutely dark cellar. Examine it from time to time and when flowers have been formed, bring it out for thorough inspection. Then see whether a few hours' exposure to bright sunlight will make any difference in its appearance. The effect of sunlight might also be tried on mustard seedlings grown in the dark.

8. Have six seedlings about the same size in a pot each. After the fourth leaf has spread and the fifth is showing, cut off the top part of the plant at a point just a little above the fourth leaf in three of the plants. Keep the other three for comparison, and some time later note whether the loss of the end of the stem kills the plant, or whether it only has some effect on its development.

9. Soak a sufficient number of white mustard seeds overnight. Then spread them out on blotting-paper so as to remove surface moisture. Place them in a bottle to a depth of an inch or so and keep the bottle stoppered for a day. Then remove stopper and immediately introduce a lighted splinter. Without naming any particular gas except air, draw a conclusion from the result noticed, but first try the splinter in a similar bottle that has not had seed in it. Into a second bottle with seed, introduce a little lime water, and shake up. Take another small portion of lime water and blow into it for a few seconds through a glass tube. Draw another conclusion, again without naming any particular gas. Would a room with the floor covered to the depth of 3″ or 4″ with seed just beginning to germinate be specially healthy, or the reverse? Give reasons.

10. Find whether seed will sprout quickly if sown in autumn.

11. Put some mustard seed in a bottle containing a little water, but filled with coal gas instead of air.

12. Try which of these three grow best—seeds sown in (*a*) damp peat, (*b*) wet clay, (*c*) fine sand once watered.

13. Hang some seeds in a small muslin bag above the surface of water in a bottle, taking care that the seeds do not get wet or touch the water.

14. Sow several sets of mustard seeds and put them under different temperature conditions: (*a*) living-room, (*b*) chimneypiece or near fire, (*c*) outhouse, (*d*) warm cupboard. Read temperatures and watch results.

CHAPTER VIII

THE BROAD BEAN

Material and apparatus required.

For demonstration.

One 4-inch pot.
Sand or potting soil to fill it.
Two beans, one of which has been soaking in water for 24 hours.

For individual observation.

The above for each pupil or between each couple.
A quarter of a pound of beans will suffice for 24 pupils.

Characters of Seeds. Compare a broad bean with any ordinary seeds, say turnip, candytuft, apple, grape, and perhaps you will first notice the difference between the bean and these other specimens. The bean is much larger, but this ought not to prevent us from noticing the points of resemblance. All these seeds are dry, hairless and of a somewhat indefinite colour, and so is the bean. This naturally makes us suspect that the bean is what each of the others is, namely, a seed. If its size inclines us to class it as a fruit like the acorn and the hazelnut, we have only to recall the fact that it came out of a pod to be sure that this cannot be.

From the fact that the bean and many other seeds have qualities which distinguish them from the other parts of the plant, we may conclude that these qualities are of special use. Just as the bright colour of petals, the greenness of leaves, the length and suppleness of stems and branches help these organs to play their part in the life of the plant, so the dryness, hardness, and other qualities of seeds are not accidental, and it would be a good exercise to try and discover in what particular way each quality is of use.

Method of Study. Having guessed from its being produced in a pod and from its external characters that the bean is a seed, we proceed to find additional proof of this by examining (after softening the bean by soaking it for some hours) the inside parts. Another method of getting acquainted with the interior of the bean is open to us. Instead of taking off the outside skin and looking for the young plant which it covers, we may sow the bean and allow the embryo in the natural process of germination to reveal itself. There is no better way of understanding the organs of a plant than to see them develop and to watch them in the performance of their functions.

Beans in Pots. In order to show the stages of germination in the bean, take a piece of paper about 30″ long and 6″ to 8″ in depth, and rule it off into portions about 4″ in breadth. Begin at the left hand and in the upper portion of the first division draw a dry bean. Make it once and a half or twice natural size and show the black mark by which it was attached to the pod. Now soak the bean for a day and draw it to the same scale again, this time in the lower half of the first division, taking care to show the changes that have been caused by the soaking. The bean may now be planted in sand or potting soil and left to germinate. At this stage no light is necessary, and the pot may be kept in a cupboard. When the root begins to show, a drawing may be made in the second division of the paper. The third and remaining divisions should in like manner be filled in order with the later stages in the development of the seedling. If handled carefully and not allowed to dry when out of the pot, a bean may be removed and replaced many times without the process of germination being very much interfered with. Drawings therefore may be made at intervals of a day or two, and each space in the paper ought to show a stage distinctly in advance of the one before it. In the last space there should be a complete seedling with a well-developed root, a short stem and leaves beginning to spread out.

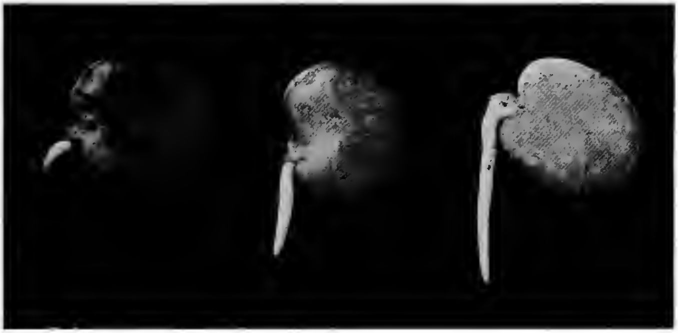

Fig. 9. First stages in germination of broad bean.

The Root. In making these drawings special attention should be paid to the root, a part of the plant which is indispensable, but which is more apt to be overlooked than stem, leaves and flowers. As germination proceeds some very important facts about this underground organ become perfectly clear. First, we may observe that the root shows signs of activity before any other organs of the embryo. Secondly, after it has thrust itself out a little and burst the seed coats, it grows straight down. Thirdly, it steadily increases in length. This should be tested by exact measurement each time a drawing is made, the length being recorded on the paper. Care should also be taken with the tip of the root, which being intended like the head of a worm to bore its way through the soil has a similar shape. By fine shading it is possible to show that the tip differs in colour from the rest of the root.

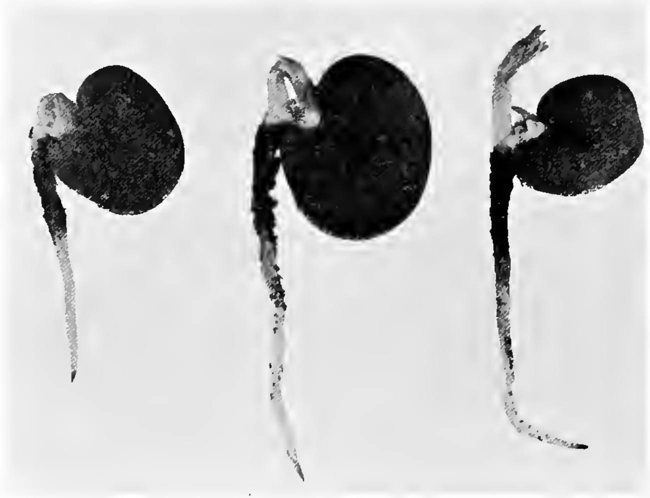

Fig. 10. Early stages in the germination of the broad bean.

After the root has elongated a little it will be found on removal from the pot to have small particles of soil adhering all over its surface, except for a short distance back from the tip. In a later stage small excrescences make their appearance in the upper portion of the root. In the next stage these will have developed into root branches which, in all details except direction, repeat the character of the main axis, showing the same tendency to annex particles of soil, the same steady increase in length and the same peculiarities of colour and shape at their tips. All this should be faithfully reproduced in the drawings.

Direction of Root. Many questions are suggested by the above facts. For example, why does the root grow downwards? A simple experiment may be arranged which, if it does not answer the question, will at least throw some light on this, and show that the downward direction is not by any means accidental. Allow a bean to grow in the usual way till the root is about two or three inches in length, and then turn it upside down and leave it for a couple of days. The root will then have turned down and the stem will have turned up, and thus both organs will again be growing in their original directions. We might also enquire why the particles adhere to most of the root and yet not at the tip, and what advantage results from the root branches assuming directions different from that of the main root.

The Stem. After its more tardy appearance the stem claims attention side by side with the root, to which it forms a very instructive contrast from the earliest stages, as, for example, in the way it gets out of the seed. The root has a very direct method of emerging, its tip being pushed right through the seed coats. The stem's method is more indirect, as it actually backs out and the first part to get clear is not the tip. The mechanical device by which this is

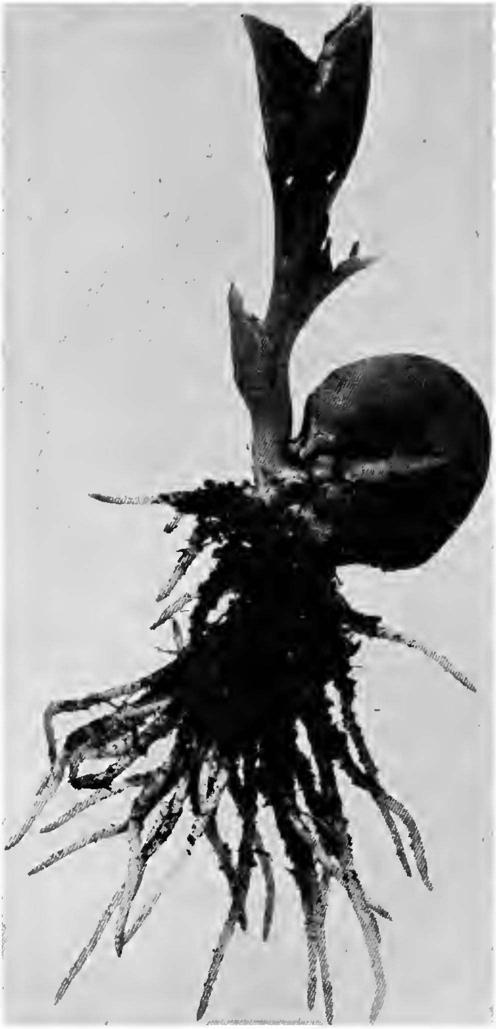

Fig. 11. Seedling bean. Note the form of the tips of the root fibres and the soil adhering to their upper portions.

accomplished is worth observing. It consists of the formation of an arch or elbow in the young stem. By the vigorous growth of the portion nearer the root than the bend, the free end is literally dragged from its hiding place within the seed. Thereafter the bend disappears and the stem's hitherto concealed tendency to grow erect is clearly shown. Under accidental conditions the stem may grow straight from the first, actually forcing its way right through the seed and coming out almost opposite the usual point of emergence. From this we may conclude that growing organs exert considerable force. It is true that in some respects the stem agrees with the root. Both are elongated and go on for a considerable time increasing in length day by day and both give off lateral extensions or branches which resemble the main axis that bears them. There are, however, many essential differences between these two leading parts of the plant's body. In particular, there are the respective directions in which they grow. The root refuses to grow up. The stem will not grow down. Each is manifestly adapted to the medium in which it grows, the root boring in the solid ground, the stem spreading out its flat, green leaves in the light and air.

The Seed-Leaves. The attractive activity of the root and stem must not be allowed to take all our attention away from other less obtrusive but equally important organs. From opposite sides of the enlarging parts of the plant and near the junction of the root with the stem, two bands, with a slightly upward direction, pass into the seed. On removing the seed coats, it is seen that each ends in a large, thick, flat object with a roundish outline, but the two are pressed so closely together that they seem at first to form a single mass occupying all the space inside the seed coats. It is not very difficult to find the root of the young plant or to identify the stem, especially as both of these organs soon grow large and assume an appearance that makes it almost impossible to take them for anything else than what they really are. But these white biscuit-shaped organs never stir, never get any larger, in fact get thinner as the root and stem get bigger. What are they? What is their use? Perhaps the latter question is the easier of the two to answer. We readily suspect that they contain a supply of food, which, being conveyed by way of the bands to the elongating root and stem, makes these two organs more or less independent of the environment as long as the store lasts.

In regard to the former query—what are they?—there is one point perfectly clear, and that is that these organs are not separate from the plant itself. They are distinctly connected with the central axis, which is composed of the root and the stem, and therefore they are as clearly part of the young plant as the root and the stem themselves. This seems so simple and so natural a conclusion, that it is hardly necessary to emphasize it. All the same, one is apt to fall into the mistake of speaking of the root and the stem as the young plant, and of these large, flat organs as being joined to the young plant, which would be an inaccurate way of expressing the facts. Now what parts are they? As we have already got a stem and a root it will not be surprising if these flat organs turn out to be leaves. They are evidently lateral appendages of the stem, and might therefore also be branches. In shape they are certainly more like leaves than branches, but this would not be conclusive evidence. When, however, we find afterwards a small bud developing just above their points of junction with the stem, there seems little doubt that these organs are leaves in disguise. As a matter of fact they are the lowest as well as the earliest leaves the young plant has and are known as seed-leaves or **cotyledons.**

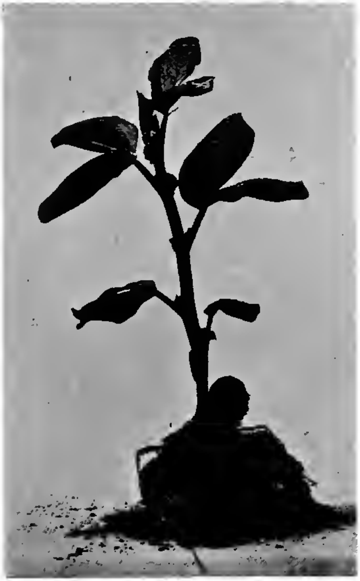

Fig. 12. Seedling bean with seed coat still visible at base of stem.

Foliage-Leaves. A striking contrast to the seed-leaves is furnished by the ordinary or foliage-leaves which are gradually produced as the plant grows upwards. At first they are small and crowded at the upper end of the stem, but they enlarge and unfold, gradually assuming an approximately horizontal position. The first fully formed leaves are some distance up the stem, and in the space between them and the seed-leaves we shall find some rudimentary ones, which should be compared both with the seed-leaves and the others that are higher up. With its root developed and branched, and with the first green leaves spreading from the stem, the bean is no longer a seed but a seedling.

The Whole Plant. If desired, the seedling may be left in the pot and allowed to grow to its full height of a foot or more. From the erect square stem a considerable number of leaves will spread. Nearer the top flowers will appear, and later we shall have pods and inside them beans, that is, seeds. The circle has been completed and we are back at the starting point.

EXERCISES

1. Examine a soaked bean and make drawings to illustrate its structure.

Show the following separately:

(*a*) whole bean.

(*b*) scar of attachment to pod (the hilum), and small opening (micropyle) at one end of it, from which water oozes if pressure is applied to the sides of the bean.

(*c*) the embryo—that is, the seed minus the skin.

(*d*) the radicle (the young root), with adjacent portion of cotyledons.

(*e*) the embryo with its cotyledons separated so as to show the stem-bud (plumule) and the bands of tissue that run from it to the cotyledons.

(*f*) the embryo with one cotyledon removed so as to expose the plumule, which will be seen to be not in the same straight line with the radicle.

2. Write a description of the bean and its structure, with some reference to the use of the various parts.

3. Write brief descriptions of other common seeds, confining your remarks to the external characters alone:

Date.	Grape.
Almond.	Walnut (remove the shell).
Pea.	

4. Examine carefully the structure of some of these seeds: hazel or oak, orange, castor-oil, and say wherein they differ from or agree with the bean.

5. Describe the germination of the bean, tracing it through its various stages.

6. Compare a seed with a winter bud, pointing out both resemblances and differences.

7. Sow a number of different kinds of seeds, and when the seedlings have developed, make drawings of them alongside of each other so that they may readily be compared. The following might be included: kidney bean, sunflower, vegetable marrow, pea. Some will be ready sooner than others, but space can be reserved for the later ones. It will be instructive if in each case several stages are shown.

8. Soak a number of beans and sow them in sets of six under the following conditions:

(*a*) as usual.
(*b*) without the seed coats.
(*c*) with one of the cotyledons removed.
(*d*) with the greater portion of both cotyledons cut away.

Allow these to grow for a few weeks and then compare and record results.

9. Choose twenty-four good beans and divide them into four sets of six each. Allow one set to soak in cold water for a day. A second set may be allowed to soak for the same time, but the water may be poured on them from a boiling kettle. A third set, after soaking for a day in cold water, may be dropped into a vessel of boiling water and kept there for two minutes. The fourth set may be left as they are. Take four pots of suitable soil and sow one set of beans in each pot, or sow them all in four rows in the same box. Label each pot or row, and after a fortnight or three weeks take out the beans and write an account of the chief results illustrated by one or two drawings made to scale.

10. After a seedling bean has developed a root about two inches long, mark off spaces a millimetre each from the tip backwards for an inch. The marking should be done with Indian ink and then the bean should be placed in sand (not too wet), or in a damp atmosphere. Examine after several hours and draw a conclusion from the change that has occurred.

11. Grow a bean till it has a straight root of about two inches. Then plant it upside down covering the whole plant. Examine after two or three days.

12. Compare the flowers of the (*a*) bean, (*b*) lupine, (*c*) sweet pea. In what respects are they alike? How do they differ?

CHAPTER IX

OPENING BUDS

Material required.

For demonstration.

A series of horse-chestnut buds and shoots (each in a separate vase of water) showing distinct stages of development.

For individual observation.

A single bursting bud for each pupil. This should be kept fresh and the progress noted at successive lessons.

In the great northern forests, the sombre pines retain their green colour all the year round. In our own country many trees, like the beech, the oak, the ash, are bare in winter, when they apparently consist of nothing but stem and branches, but as spring proceeds, all these are hidden in a mass of splendid foliage, and once more become the homes of singing birds, whose voices come to us from the green recesses. The change is as astonishing as it is complete, and if witnessed by anyone unacquainted with the wonders of the vegetable world, would surely seem little short of a miracle. On a single tree there may be ten thousand, or a hundred thousand, or perhaps even a million leaves, where not one was to be seen before. We understand better how this can happen (but need not admire the results any less) when we realise that these leaves were really formed beforehand, and that their appearance in spring is due to the bursting of buds which sheltered them through the winter.

It is certainly a refreshing sight (and remember that it is not in every part of the world that this transformation scene can be watched) to see tree after tree casting off the fetters of winter, and to watch the new green creeping along a countryside; but if we wish to appreciate all the details of the wonderful process, we must not spread our attention over a whole wood or a whole tree, but must concentrate it on a single bud. Buds of ash, oak, beech are all suitable for examination, but perhaps a horse-chestnut, which has all the parts large and distinct, will do best.

The bursting of the bud and the subsequent development of the leafy shoot may be watched outside, but in this case the observations will be spread over a good many days or even weeks. Another method may be adopted. We may be able to gather from a tree, or from several trees, buds and shoots at all or nearly all stages of progress. These may then be arranged in the order of development, the whole course of which is before you at the same time. Thus it will be possible to place alongside of each other any two stages that it is desired to compare, and easy then to record points of difference and agreement.

When the series has been arranged, five or six representative stages should be selected and very carefully drawn or described.

Fig. 13. Class making notes on buds of horse-chestnut tree.

There are many questions to be answered about the bud. Are the leaves green while still inside? Are they folded or crumpled up? How many leaves come out of each bud? Does anything besides leaves come out? By what process are the leaves separated from one another? Are the scales arranged in any particular way? What becomes of them when the bud opens? Do they grow into leaves? With such enquiries in view, we proceed to examine the various stages.

The first drawing should be one of a piece of branch or twig, as nearly in its winter condition as possible. It looks a very simple matter to draw a piece of the branch with the elliptical bud at its tip, but we must make sure we include all the detail. There are some marks on the branch which must not be omitted. Two of these are on opposite sides of the branch, just below the bud. These are in the shape of a horse-shoe and the resemblance is carried as far as the nails, which are very neatly represented. Further down comes a second and then a third pair of these characteristic markings. Still lower down, there occurs a number of lines very close together, which seem to run round the branch. Beyond these comes another series of three pairs of shoes, then again closely set lines, then more shoes and so on. In addition to the bud at the end, smaller buds may be noticed fixed on just above a shoe. If these side buds are capable of producing branches of the main branch, we might expect to find such lateral extensions further back. Are they there, or do the side buds remain?

The Bursting Bud. So much for the unburst bud and the branch, whose sticky tip it forms. Our next study is the bursting bud. It is still sticky, still where it was, but bigger. The scales have grown and are loose at the further end, and soft woolly finger tips of leaves have been thrust straight out as if in an attempt to seize the chances of a freer life beyond the boundary that has circumscribed their activities all the winter. Having pushed aside their prison walls they are not

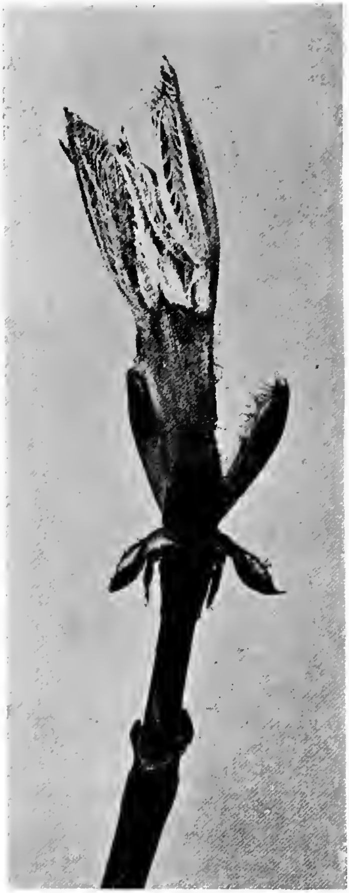

Fig. 14. Opening horse-chestnut bud. The leaves of the first pair are just beginning to unfold.

long in getting further out, and soon the whole hand is out—two whole hands indeed. These are placed palm to palm with the long smooth fingers folded along their middle line and with lengthening stalks between them and their starting point in the bud. This will make an instructive third study. The fourth stage is that of the spread hand. The palms by means of their stalks, which each describe a right angle backwards from the

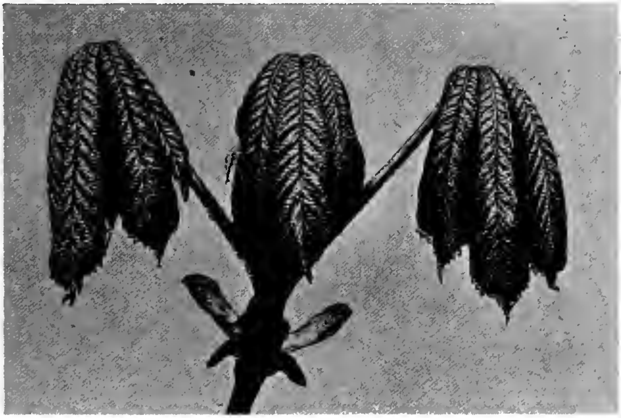

Fig. 15. Horse-chestnut shoot showing first and second pair of leaves.

middle line, are now as far as possible from each other, and the fingers of each have separated and become flat. Already between the stalks of the spread leaves a second set of delicate fingers points to the sky. These belong to a second pair of leaves, which repeats in all details the movement of the first. But note two points. The second pair is higher up than the first and its leaves point in directions at right angles to the directions of the leaves below them. If the first two leaves should happen to point north and south, the second two would point east and west. Such an arrangement is known as **decussate.** A sixth stage would show the first and second pair both spread and a third pair just emerging. The seventh stage would show six well-formed leaves, the third pair being the highest, that is, furthest from the original position of the bud. This last stage should be drawn as seen from above, to show that the six leaves are so placed as to shade each other as little as possible, forming what is known as a **leaf-mosaic.**

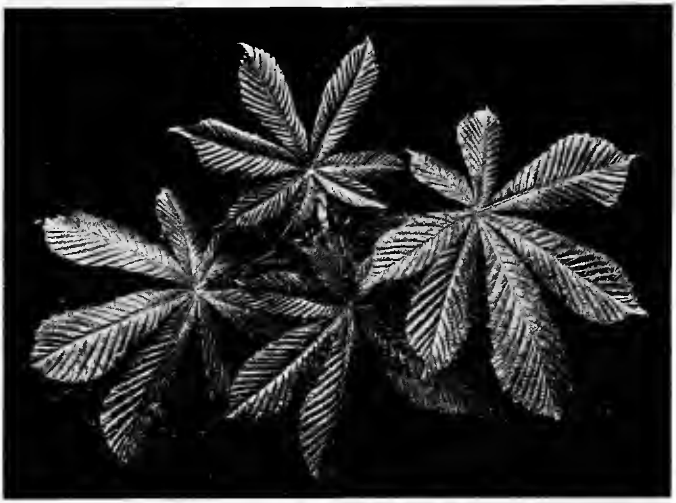

Fig. 16. Horse-chestnut shoot with expanded leaves forming a mosaic.

Shoot and Bud. We may now stop to sum up the results. We began with a bud and now we have a shoot. The most notable part of the shoot consists, of course, of the large compound leaves with their finely formed leaflets and long stalks, but there is something else which must not be overlooked. It is easily seen, if we examine the shoot, that between the original position of the bud (which, although the bud is no longer there, is clearly marked) and the attachment of the stalks and the lowest pair of leaves, there is a piece of green stalk. Another piece of stalk called an **internode** lies between the first pair and the second pair of leaves and still another piece between the second pair and the third. Above the third pair we find the stalk ending in the bud, which has never disappeared, but has only moved forward from its winter position to this new one, by the growth of the central stem-like structure. This therefore as well as the leaves has been developed from the bud. The length is precisely the distance between the first position of the bud and the point to which the growth of the axis has now carried it. A bud then gives rise to a shoot, and a shoot consists of axis or stem and the leaves attached to this. We may include the bud at the tip and also smaller buds in the axils of the leaves.

There is certainly not much risk of confusing the bud with the shoot, for they are about as different as could well be, but it may be of use to put the strong contrasts into words. The simple outline of the original bud has given way to complexity of external structure, while the brown colour of the scales has passed into the lively green of the leaves. But we may take a broader view of the matter than that. It is this. In the bud everything was small and packed closely together, while in the shoot the organs are larger individually, are spread out and separated from one another. This brings some disadvantage. Each leaf is now out on its own. No more protection from bud scales or closely pressed neighbours. The rain now wets them. The wind dashes them about. They have entered on the struggle for existence. They are in full touch with the environment. We may therefore enquire what is the use of all this unfolding, spreading, stretching, separating. There has been an extraordinary increase of surface. The area of the surface of the original bud may perhaps have amounted to a quarter of a square inch, and now we have six large leaves, each with seven leaflets, with a total area of over a hundred square inches, or double that if we include both surfaces. Take account of all the leaves of the tree and then we may reckon not in square inches but in acres. What is the use of this extensive green surface? Is it to get into contact with the air, or to catch the rain, or to intercept the light? Can we settle which? All these things are useful to the plant, but it does not follow that it is through the medium of the leaf that the plant derives benefit from them. It is evident that the leaves in the main assume a horizontal position, and we may conclude that this position has something to do with the matter. If the only thing the leaves wanted was air, it would not be necessary for them to be horizontal. The air would get at all parts of the leaf just as well if they were vertical, but then they would miss a lot of rain and a lot of light. We have already seen how the leaves are arranged in mosaics, which secures a maximum of illumination over all the leaf surface of the plant. It catches also a maximum of rain. Is it to catch the rain or to catch the light that the leaves spread out horizontally and do not shade each other? As there are no means by which the rain that wets the upper surface can get into the interior of the leaf, we assume that it is chiefly to catch the light that the leaves are thus arranged. It is quite certain that if the plant had wanted air alone, not only would the leaves not have been so uniformly horizontal, but the sum total of the area would not have been so great. This can easily be proved by growing plants in the dark.

Scales. But we have been forgetting the scales. As the leaves have been spreading, so also have the scales. Not only have they described two right angles as if anxious, after their work was done, to get completely out of the way, but—what is not so easy to explain—they have actually been growing as if infected with the energy of the leaves themselves. They almost seem to mimic the leaves, spreading like them, growing with them, and setting the example of falling off, leaving also behind them marks which resemble, except in size, the scars which the leaves themselves will make. With so many points of agreement, we can hardly doubt that the scales act in this way because they are fundamentally leaves—leaves modified for a special function. If we desire further proof of this we have it in the way they are fixed to the branch in decussating pairs just like the ordinary leaves. Whether they represent whole leaves or not is another question, but that can be settled by an examination of the scales themselves. Some of them will be found to have developed, at their free end, small organs which are easily recognised to be leaflets. No one can further doubt that the scale is the homologue of the leaf stalk.

With the fall of the last scale, little trace of the bud is noticeable, and the shoot will soon be nearing its maximum of development. The large leaves have completed their spreading and unfolding and to a large extent their growing also. They are now entering on their working period, during which they go on breathing

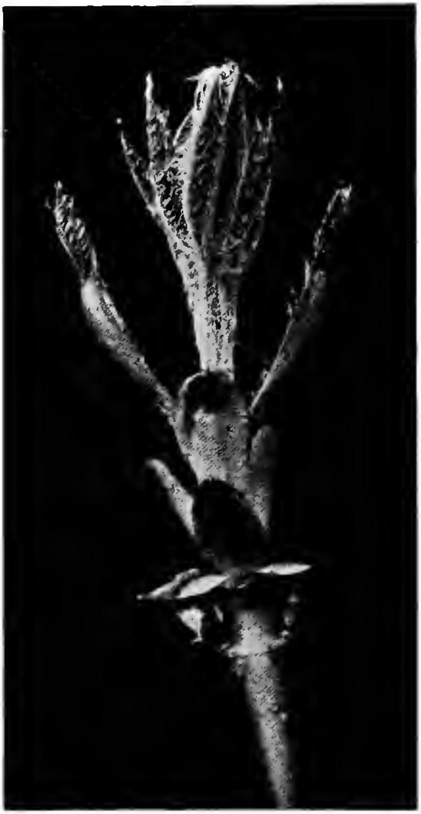

Fig. 17. Opening horse-chestnut bud. Leaflets have developed at end of the two highest scales.

vigorously, transpiring vigorously and producing during the hours of light the food of the plant. This energy is kept up for months, but with the advent of autumn the leaves, now no longer in the fresh green of their youth and perhaps battered by the equinoctial gales, gradually become less and less active and at last give up the unequal struggle with a hostile environment. Faded and useless they fall to the ground. One part of the shoot is, however, permanent, and that is the axis or stem-like portion to which the leaves were attached. It already has a bud at its tip from which will come next year another new shoot with next year's leaves.

Sleeping, awakening, working, fading—these operations make up the circle of the leaf's year, and we may study it under all these conditions. At no season are leaves of more interest than in spring. On emergence from the bud they unfold and spread and grow with a rapidity almost kaleidoscopic, displaying the energy of young life as they make themselves ready to catch as much as possible of the sunlight of our short and fiftul summer.

EXERCISES

1. Select buds in instructive stages and make drawings.

2. Make a list of the differences between leaves just ready to come out of the bud and leaves that are fully developed.

3. Describe some of the chief changes that occur in the process of opening, and point out beneficial results in each case.

4. What is meant by a leaf-mosaic? Draw one either from the horse-chestnut tree or some other, say beech. What benefit accrues from such arrangements? Mention a few plants that show those mosaics.

5. Try if the shoot will develop in a vessel of water in an ordinary room and also in a dark cupboard.

6. Get a portion of a branch some feet long. Make a list of the years represented in it, and record the length added each year.

7. The leaves of horse-chestnut are decussate, but in many trees and other plants there is a spiral arrangement.

Examine shoots or stems of several and record their phyllotaxis (leaf arrangement). Common fractions are: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$. (See Chapter I. page 10.) The following, besides others, are suitable for examination: apple, hawthorn, blackberry, grass.

8. Draw a fully developed shoot with a portion of the branch of which it is a prolongation. Then draw it as it would have been if two side buds had developed instead of the single terminal one. Draw it again as it would be next year if side buds a second time carried on the growth.

Distinguish between branch and shoot.

9. Collect the leaves of some typical British trees—ash, elm, poplar, beech, lime, etc.

Make drawings of them alongside of each other and name the shape of each. The leaves might also be pressed and mounted, with names.

10. Keep a diary during April and May. Note daily the condition of different trees and whether they show unopened buds, bursting buds, open leaves.

11. In March take indoors twigs of different trees and put them in water. Does any change occur after a few weeks?

12. Use the pressed leaves from question 9. Put one in a photographic printing frame between the glass and a sheet of ferroprussiate or other sensitive paper. Can you get a print showing the veins as well as the outlines?

SUMMER

CHAPTER X

THE TULIP

Material required.

For demonstration.

Several large tulip plants showing all the parts from roots to flower.

For individual examination.

One cut tulip flower for each pupil.

A few unopened tulip flowers to show unburst stamens.

General Structure. The general structure of the tulip is so simple that we can describe it in a single sentence. When we say that from a large scaly bulb with a bunch of fibrous roots hanging from its underside, a stiff, erect, cylindrical stalk, partly concealed by a vase-like set of large leaves, ends at the top in a solitary but gorgeous flower, we have really sketched it. It would be difficult to do equal justice in so few words to a large and much branched horse-chestnut tree in bloom or to a laburnum tree or even to a primrose plant, but it would be excellent practice to try. It would be easier to succeed with such plants as foxglove, harebell, hyacinth or snowdrop. In such descriptions it is not enough to enumerate the various organs. These must be brought into relation with one another.

It is certainly remarkable how few parts the tulip plant has. The root fibres, to be sure, are numerous, but beyond that everything keeps to low numbers. There is one bulb, one aerial stem without branches, three or

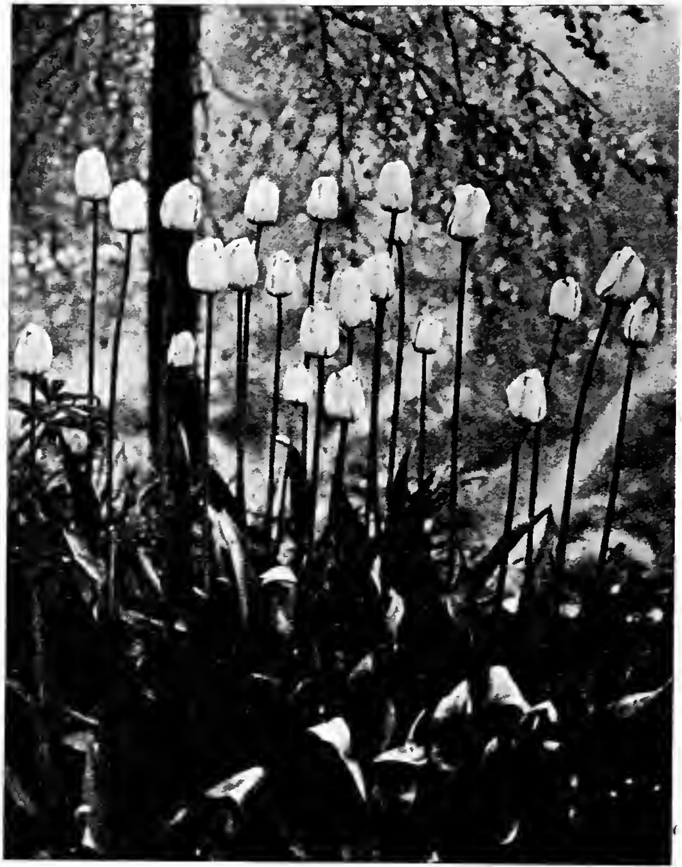

Fig. 18. Darwin tulips.

four leaves without stalks, and only a single flower. If, however, its organs are few, they are large and well suited for inspection, while one is also attracted to the study of it by the beauty and imperial glory of the blossom.

Chief Parts. Before dealing more particularly with the flower itself, we may make a passing reference to the other parts. Beginning with the bulb, we may prove that the membranous outer covering as well as the fleshy scales below are all modified leaves. Then making a section we may note the formation of young bulbs, which reproduce the plant, as well as the connection between the cylindrical part of the stem and its solid underground portion, to which the scales are attached, and which is therefore to be reckoned part of the stem just as much as the more easily identified portion above ground, which bears the ordinary foliage leaves. The chief interest attaching to the green part of the stem, apart from its smooth surface and rounded shape, is the way in which the strands of conducting tissue in its substance run up and down without forming a ring of wood as they do in many well-known plants. The irregular arrangement of these strands may be readily seen in a cross section of the stem. In the leaves, which are so placed as to point in three different directions, these strands are represented by the distinctly parallel veins that ridge the surface of the large, simply-shaped, but elegant blade.

Relationship. The tulip is closely related to such pleasant plants as the lily and the lily of the valley and also to other less showy and less attractive ones such as the onion and garlic. Like the members of the larger and more useful family of grasses, it is a monocotyledon. **Monocotyledons** are usually very readily recognised by various surface characters, and perhaps the beginner is apt to think of these merely as signs which are handy when you want to classify, instead of realising that the characters so easily observed are only part of the whole truth, which is, that the plant is a monocotyledon through and through—in its every fibre. No matter what organ or what part of an organ you fix on, the monocotyledonous character is there, whether it be easily observed or not. The roots of the tulip are monocotyledonous roots. The mere occurrence of a bulb at all is significant of the relationship of the tulip, and when the scales are examined, the monocotyledonous character is apparent in them too. The same with the stem, and also the leaves with their triquetrous arrangement. Every vegetative organ of the plant has the same story to tell, and the flower also echoes the fact that the plant is a monocotyledon to its core, to its inmost cell.

The Floral Plan. Now we come to the flower. Its various organs are so large that little time is needed to discover that there are six flower-leaves, six stamens and three united seed-vessels, and we may proceed at once to the way in which they are arranged. By means of a simple diagram, we may make very plain the symmetry of this most regular of flowers. First it is necessary to note that the large brightly coloured flower-leaves are not all at the same distance from the floral centre. To represent this diagrammatically, two circles will be required, each with a different radius, but described from the same point. Careful examination of the stamens, especially of their bases, will show that they also are in two whorls, three of them being slightly, yet distinctly, further from the centre than the others. The three outer ones lie on the same three radii as the outer flower-leaves. Perhaps the seed-box is a little more difficult to deal with, but by noting what its flat sides face and what its angles point to, its position becomes definite. As the diagram to be made is of the nature of a ground-plan, the seed-box must not be shown as it appears standing up in the middle, but as seen when cut through horizontally so as to show its internal division into three compartments. The stigmas which are above the plane of section may have their direction indicated by dotted lines. Altogether there will be five circles and three organs on each of these. When the diagram has been made, find out either from it or from the original flower, along how many lines the latter may be divided into two equal halves. Draw the lines showing these divisions. As the halves produced by section along any one of these lines are all absolutely identical in their details with the halves produced along each of the other two, the tulip is said to possess perfect symmetry. We shall arrive at the same result if from the centre of the diagram we draw six radii, one to the middle of each flower-leaf. If the diagram has been accurately drawn, each of these radii runs through the middle of a stamen and three of them bisect a seed-box. We may go further and calculate the angular distance between any two flower-leaves or between an outer one and an adjacent inner one, and in this way be convinced of the mathematics of the flower.

The Floral Functions. Having seen how it is arranged, let us next enquire how it works. It is only necessary to bring a closed tulip into a warm room to see that it is sensitive to outside influence. The heat soon makes the coloured leaves spread out widely and they will remain in this position till the flower is removed to a colder place, when its leaves assume their former positions, giving to the flower as a whole the appearance of a richly coloured egg. In this admired position they form a sheltered chamber, within whose gaudy walls the delicate parts of the flower are secure from the inclemency of the weather. When rain falls, the drops run down the sloping glossy outer surfaces of the flower-leaves and the inside parts are as dry as if they were under a great family umbrella. It is only when the sun sheds genial warmth that the leaves fold back and open a window to the sky. It is easy therefore to conclude that whatever other function the perianth, as the flower-leaves are collectively called, may have, its office is partly at least a protective one and it is evidently provided with a mechanism that enables it to perform this very effectively.

The Stamens. Passing into the chamber of the flower, we see the stamens marshalled in a ring round the central organ, each with its long, smooth, yellow head supported by a flat, broad-based stalk which tapers to a point where it joins the head. As everybody knows, the stamens have a very special part to play as pollen-producers. Countless grains of this yellow dust are formed inside the stamen head and it is interesting to trace, with the aid of the microscope, the series of cell divisions of which it is the final result, but we must at present be content with observing the method by which it is made available for the purpose of fertilization, in other words, how it gets out of the head (or anther) in which it is formed. To understand the process it is necessary to select specimens from flowers at various stages. There will perhaps be little difficulty in finding a stamen with a flattened head all dusted over with the yellow pollen, but we must also find another whose anther shows a smooth rounded surface free from pollen. Finally, we must search for others in intermediate conditions. We may find one just beginning to split along two lines that run downwards and another that shows the splitting carried to the base of the anther. By the widening of the slits the anther is

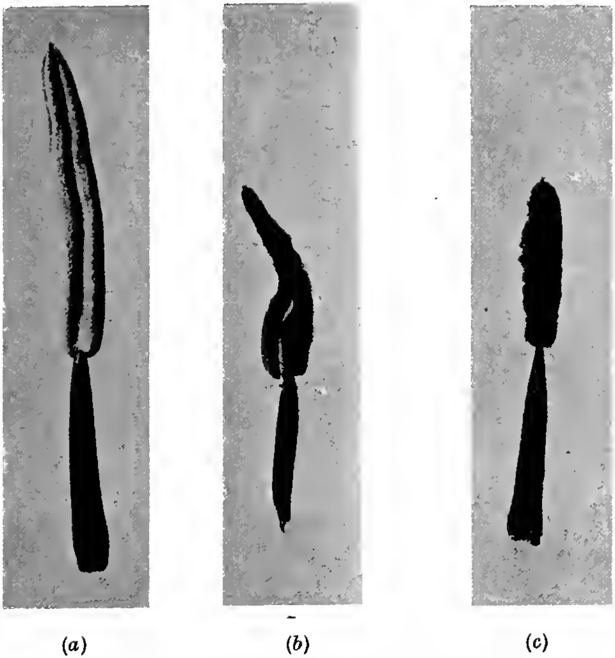
(*a*) (*b*) (*c*)

Fig. 19. Stages in the bursting of stamens.
(*a*) unburst. (*b*) bursting. (*c*) burst.

practically turned inside out so that the pollen has every chance of being distributed from the exposed surfaces of the now flattened head. It is noticeable that the slits occur on the side of the anther turned towards the centre of the flower.

Seed-box. From an old flower which has ceased to respond to changes of temperature and whose stamens have shed all their pollen, we remove the piece at the centre. Erect and stiff, this three-sided, parallel-edged, glossy and green object seems incapable of any active service in the life of the plant. It does not look as if it could open and shut like the perianth leaves. Its top cannot move about like the anther of a stamen. How does this pistil work? It certainly looks as if it were intended to play a waiting game. Such is indeed the fact. Cross and vertical sections show the regular internal arrangement, especially the three separate cavities, each containing a large number of very small bodies looking very like seeds. Before deciding whether they are so or not, let us examine a flower that has not been open at all. Its smooth unburst anthers show no external trace of pollen whatever. Here the pistil, which is the name for the central piece as a whole, is small, and from the greater size in the other flowers already examined we infer that rigid as it is, it is at least able to grow. On cutting up the smaller pistil we find the same white objects which are so readily taken for seeds. In this case we need not hesitate to say that they cannot possibly be so. Ovules they are in the meantime; seeds they may be called by and by, but that depends.

Fertilization. The change from ovule to seed occurs inside the seed-vessel and does not attract attention, but it is exceedingly important. It can be effected only by pollen. Into an unopened flower no pollen has come from the outside, and as its own stamens have not burst to liberate their supply of the stimulating dust, the ovules must remain what they are until this critical event takes place. In the seemingly inert pistil, great operations are in progress even before the flower opens. The ovules are being formed. At last they are ready, but the only outward sign of this is the condition of the three stigmas that radiate from the centre of the top and wait for the pollen to come. At this point all the organs of the flower co-operate in securing the all-important change. The flower-leaves fold back, the anthers burst and their powdery contents fall on the waiting stigmas. These should now be examined to see if any grains can be detected on them. If they can, we then say that the stigmas have been pollinated. And now there is a chance for the ovules inside. A pollen grain having settled on a stigma very soon begins to send out a delicate tube. This worms its way gradually into the cavity containing the ovules, and gets into contact with one of these. Fertilization takes place and this means that changes are set agoing which end in the production of a seed. The chief of these changes is the development inside the ovule of a miniature plant, known as the embryo. All this time the petals still open and shut, and the stamens continue their bursting, and pollen is continually arriving at the stigmas. Perhaps a hundred pollen-tubes are hurrying towards the waiting ovules and in due course a hundred ovules may be fertilized. The show is over. The petals fall off and the stamens wither up. The pistil, however, is still in the middle of its work. Inside it perhaps a hundred embryonic tulips are growing inside a hundred seeds, whose increasing size demands increased accommodation, which by continued growth the pistil is able to supply. In garden tulips effective fertilization seems to be the exception, but if, after petals and stamens have gone, the pistil goes on enlarging till it is about twice the length it had in the opening flower, then one may as safely conclude that it contains seed as that the pistil of an unopened flower contains ovules. There can be no seeds among the ovules in an unopened flower, but among the ripening seeds of a later stage a few shrunken ovules show the fate of the unfertilized.

The Withering Plant. A glance at a tulip in its last stage is instructive. Its fine broad leaves have shrivelled up. The once green and juicy stem is hard and dry. At its upper end instead of the gorgeous blossom there is only a seed-vessel, which is now the most prominent feature of the whole plant, and it too is no longer glossy and fleshy and green, but brown and dry. The work of stem, of leaf, of flower is now complete, for from three gaping slits that run up and down the seed-box a plentiful supply of seed is ready to fall, and each seed contains a germ, which under suitable conditions is capable of recreating the vigour and beauty of the parent plant. But the tulip has not all its eggs in one basket. There is hope for the species not only in the seed at the top, but at the lower end of the plant as well. Although the old bulb is getting disintegrated, young bulbs have already formed in its heart and each of these may grow into a new plant.

EXERCISES

1. Draw (*a*) the whole plant, (*b*) vertical section of the bulb, (*c*) single leaf showing veins, (*d*) vertical section of flower, (*e*) series of stamens showing stages of bursting, and (*f*) cross section of the ovary.

2. Suppose after the tulip has flowered that the bulb elongates and becomes like an ordinary stem, that the scales become leaves and finally that the new bulbs remain attached and also lose their bulb-like character and develop as ordinary branches, we shall get a very different looking plant. Draw it as it would now be. Note that when a branch or a stem has a flower at its end, there is no further growth in that direction. Indicate by shading or otherwise the portions (stem or leaf) that would under ordinary circumstances have formed a bulb.

3. Make a ground-plan (floral diagram) of the tulip as described in the chapter. Begin by describing five circles from the same centre, but with different radii.

Compare with floral diagram of daffodil and hyacinth.

4. Compare a tulip with wallflower or with wild mustard or chickweed. Tabulate the differences and similarities, arranging them under the following heads: root, stem, branches, leaves, flowers.

5. Describe in one or two sentences each the following or other similar plants at the time of flowering: hyacinth, daffodil, celandine, buttercup, primrose, harebell. The description should be made from a specimen showing all the usual parts, including the root.

6. Examine under the microscope and describe (*a*) pollen, (*b*) section of ovary, (*c*) cross section of stem, (*d*) teased portion of longitudinal cut of stem to show the tubes, (*e*) skin of the leaf (it can easily be torn off).

7. Water a tulip, preferably a white one, with solution of eosin. After an hour or two examine stem, leaves, flower-leaves, stamens, seed-vessel, and ascertain how many of these show signs of having some of the dye in them. Cut across the stem and a leaf to determine the track of the ascent. Can you make any estimate of the rate?

8. In the evening or early in the morning invert a long tin canister (such as photographic dealers sell sensitive paper in) over a tulip growing in the garden and leave it on for some hours of sunshine or until neighbouring tulips have opened. Then remove the canister and note any result. In what two respects will the resulting conditions inside the canister differ from those outside? If you think the experiment has not been satisfactorily arranged, how would you improve it?

9. At seasons of the year, *e.g.* September, when tulips are not in flower examine the flowers of the lily (*Lilium auratum*, *L. speciosum*, etc.) and compare these with descriptions above.

10. Draw and paint a tulip flower.

11. From the flowers of tulips (or lilies) grown in a pot remove all the stamens. Next pollinate some but not all of these mutilated flowers. Mark those which you pollinate. Does any change occur within a fortnight?

12. How do tulip flowers change their shape in sunshine?

13. Use a florist's catalogue to find the names of as many varieties of the tulip as possible.

CHAPTER XI

WALLFLOWER

Material required.

For demonstration.

One or two large and well-branched wallflower plants with all parts present.

For individual examination.

One flowering branch for each pupil. Two or three bunches as sold by greengrocers will serve a class of 24.

Method of Study. This plant is chosen chiefly on account of its flower. It is not enough, however, to count the sepals, petals, stamens, carpels, to note that the organs of the first three sets are free from each other, and perhaps also to note that of the six stamens two are inserted at a slightly lower level than the others. This is far too mechanical. By comparing a flower with others in the same inflorescence, by noting how the inflorescences are arranged with regard to each other, and how they are related to the plant as a whole, a much more comprehensive view is got and all the facts hang together. Then when we come to examine a single flower, we shall see it in relation to the complete plant, of which it is a part,—to the living whole, of whose energies it is a result. Each floral organ is not a sepal, or petal, or stamen, or carpel to be counted as if it were an item in an addition sum, but should be regarded as the cause of some effect. We must find out the function of each part, see how it performs it, note the signs that its work has been accomplished, and so on.

Wallflower and Tulip. It would as an introductory lesson be a useful exercise to give either orally or in writing some simple and obvious differences between the tulip and the wallflower. This would incidentally bring out some of the relations above referred to. These two plants agree in being favourite spring flowers, and further in having the various parts well distinguished from each other, the vegetative organs being very clearly separated from the reproductive ones. Then the differences come in. There is no bulb in the wallflower, which ends underground in an ordinary tap root. Above ground, the fewness of leaves in the tulip contrasts with their great number in the wallflower, where they are so thickly set that one hardly sees the central stem and its branches, to which they are attached. The large flower of the tulip is in contrast with the small flowers of the wallflower, which, however, make up for lack of size by number, following the example of the leaves. We also note that the flowers are grouped into inflorescences, and there is something attractive in the way those at the end of the branches rise up round the central stem and form a setting for the inflorescence of the latter, which takes the lead in time and size. The wallflower lacks the simplicity of the tulip, yet with its erect stem and erect branches it seems, in well-developed specimens, to have something of the same stateliness.

Inflorescence. Before studying a single flower we view the inflorescence as a whole and remark that although the central inflorescence of the plant flowers first, the central blossom of any given inflorescence is the last one in that inflorescence to come into bloom, for when those on the circumference of the inflorescence are opening, those in the centre are still in the condition of very small buds, and by the time it is the turn of these last to spread out their petals, the whole shape of the inflorescence has altered. To begin with, the flowers are approximately on the same level, but as flowering goes on, the common stalk lengthens and the fruits which are forming from the flowers that opened first are already at different levels, the first being several inches below some of the later ones. The best time to examine an inflorescence is when it is in an intermediate condition. Then many stages of the flower are represented. It is instructive to pull off flowers representative of the chief stages, and to arrange them in a way that will suggest their natural position on the plant. This will impress the development of the floral drama much more forcibly than a mere glance at them in the inflorescence, and if drawings of the series are made, the important and significant facts will be still further emphasized. Then we may realise that in the short space between the lowest flower ripening into fruit and the minute bud at the tip or centre of the inflorescence, there is an epitome of the year, and if we like to think of it so, a drama of life, in short, a reflection in microscopic dimensions of the motions of the spheres.

Flowering Phases. To begin with there is the bud in which everything is small and hidden. Then we follow the path of gradual evolution which includes the protrusion of the petals and subsequent expansion. This marks the first consummation of the bud's possibilities in the shape of a fully opened flower, with its fragrance and beauty. Then follows a decline of attractiveness, when bedraggled petals and shrivelled stamens inaugurate a process of decay, which does not end till sepals, petals, stamens, mere caricatures of their former selves, are cast off and undergo unnoticed disintegration. But this does not happen until from our point of view the fragrance has been enjoyed and the beauty admired; until from the plant's point of view colour and scent have achieved their purpose and contributed their share of help towards the desired result, namely, the securing of the permanence of the species. We must also notice that although sepals, petals and stamens are involved in a common annihilation, the central portion of the flower is still on the make. The flower fades, but the pistil affords proof that work has been accomplished, and out of dissolution there springs new life. A new year is there already and the promise of the bud ends with the promise of the seed. A fine series these flowering phases make—small bud, swelling bud, bursting bud, burst bud, opening flower, flower in full bloom, withering flower, withered flower, ripening fruit. Draw them all and print the descriptions beside them, thus illustrating the wonderful changes in bud, flower and fruit, their swelling, bursting, expanding, blooming, fading, ripening, and then later, splitting and scattering.

The Flower. Now we turn to the individual blossom, noting that a different stage is represented by each flower in an inflorescence and that any single flower goes through the whole series by itself. By looking at the inflorescence, we see the different stages at one glance. They are side by side and may be contrasted, whereas in a given flower one stage passes gradually into the next, and two stages cannot be seen at the same time.

Sepals and Petals. Choose a flower at its best, and find out as many of the important facts as possible about it. Note the four velvety petals disposed in a cruciform or cross-like manner, and think of other plants that have the same arrangement (such as stock and wild mustard), an arrangement which is characteristic of plants belonging to a group called *Cruciferae* on this very account. For convenience of reference, names are given to certain parts of the flower, the back, the front, the sides, the back being next the main stalk. When a diagram of a flower is made, the back is placed where north would be in a map, the front is to the south, while the lateral positions would be represented by east and west. With a little careful examination of one or more flowers, you can easily make certain that it is a sepal and not a petal that lies exactly at the back. The opposite sepal, of course, marks the front of the flower, and the two intermediate ones are lateral. Cut out a small square of paper and make a hole in the centre. Into this push the lower part of the flower and then adjust it so that the back sepal if folded down would point to the middle of the upper edge (the edge furthest away from the observer). The other sepals, if similarly folded back, will point to the other middle points of the sides. After the flower is fixed in this position, it is easy to see that the petals point to the four corners, and if it were a map, their directions judged from the centre would be north-east, north-west, south-east and south-west. The petals are therefore said to be **alternate** with the sepals.

Compared with the petals, the sepals make a poor show, and at first seem almost negligible, although it is not difficult to guess that one at least of their functions is to protect the flower-bud in its early stages. But the sepals of the wallflower show no tendency to fall off as the sepals of some flowers do whenever the flower opens. It is therefore reasonable to assume that there is some work left for them to do. What that work is can easily be made plain. Pull off the sepals and then shake the flower. The petals soon get out of place. So we see that the sepals acted as supports. Even this is not all there is to discover about these insignificant organs, for the lower portion of the surface of the two lateral ones, which at that part distinctly bulge, is the receptacle for honey, to whose presence both sight and taste can testify.

The petals are a decided contrast to the sepals. Their extended surface, with its colour and scent, serves to guide insects to the honey concealed within the flower. When petals and sepals are removed, the small scars they leave may be used in comparing the positions of the outer and inner portions of the flower.

Stamens. On the analogy of the tulip, we might expect to find eight stamens in the wallflower, but their number is only six. Four of them form an inner circle and lie on the same radii as the petals. Now look particularly at the other two. Round the base of each of them is a green gland, and here the honey is produced. This, as has just been pointed out, gets collected in the saccate sepals, with which these outer stamens are in line. This particular arrangement of stamens is found only in the *Cruciferae*, and is therefore a very easy character by which to recognise the members of this family.

Seed-vessel. We now come to the central portion of the flower. The observation that each of its two flat sides faces a lateral sepal, and that the two stigmas, looking like white tongues, point to the other two sepals, enables us to give the seed-vessel and its stigmas their correct position in a ground-plan of the flower. A cross section will settle another point of structure, and that is the existence of a membrane, which runs from the back to the front of the flower and thus divides the ovary into lateral halves. If this part of the flower is examined after it is turned into fruit, it will be easier to see the characteristic way in which the seeds are arranged in four vertical lines, with their stalks arising near the outside walls and not from the central part of their box.

Seeds. In each flat seed we may find a minute wallflower plant, and in its two leaves we have one reason for some of the differences between it and the tulip, for the latter is a monocotyledon and the wallflower is a **dicotyledon.**

Summary. Now it is possible to realise more clearly what might be guessed even in a cursory examination of the flowering phases, namely, that the brightness of the petals and their fragrance, and the withering of them and of the sepals, are only superficial phenomena, which we must look upon as outward signs of deeper processes. Among the latter we must surely include the wonderful fact of growth. This is exemplified in the development of the minute flower-buds, from which, at first not so large as the head of a pin, there finally emerge large and beautifully formed petals and other organs still more wonderful in the intricacy of the structure that has been evolved in the recesses of the bud. We may recall also the production of pollen, its liberation from the anther, the formation of the ovules (the potential seeds), the manufacture of honey, the visits of insects and the transference of pollen by them or otherwise to a stigma, the growth of the pollen-tube, the fertilization of the ovule, the formation of an embryo and the ripening of the seed. All this has been going on while the casual public notice nothing but the odour and the colour.

EXERCISES

1. Make drawings of seven or eight flowers to show the transition in the course of flowering from bud to fruit.

Name the drawings—bud, bud beginning to burst, etc.

2. How does an inflorescence that has flowered differ from one beginning to do so?

What advantages result from there being more flowers than one in an inflorescence, and what advantages from their not being all in full bloom at the same time?

Compare with each other the different inflorescences on a single wallflower plant.

3. Draw a ground-plan of the wallflower. The sepals are in two whorls and so six circles are required in all.

4. Draw a vertical section of a single flower in full bloom much enlarged, and show very carefully the attachment of the various organs.

5. Pull off sepals and petals and make an enlarged drawing of what is left. Name the parts.

6. Define briefly:

(*a*) sepal.
(*b*) petal.
(*c*) stamen.
(*d*) carpel.
(*e*) fruit.
(*f*) flower-bud.
(*g*) flower.

Explain fully how a flower-bud in itself and in its results differs from an ordinary winter bud on a tree.

7. Write a full and detailed description of a stamen after having examined it in various stages.

8. Mix a little sugar in water (a 10 per cent. solution will do) and put a drop of this on a microscopic slide. Dust on pollen from a bursting stamen and then put on a cover glass. Examine under the microscope. Then leave it for an hour or two and examine again. What has happened?

9. What is there about a wallflower blossom to attract insects? Name some other plants whose flowers are also attractive to them and give particulars.

Give examples of flowers with special shapes that may be connected with insect visits.

Give examples of trees, shrubs or herbs whose flowers seem to have no attraction for insects. How can their pollen be carried?

10. Define:

(*a*) pistil.
(*b*) carpel.
(*c*) ovary.
(*d*) style.
(*e*) stigma.
(*f*) ovule.
(*g*) seed.
(*h*) pollination.
(*i*) fertilization.
(*j*) cross-fertilization.
(*k*) self-fertilization.
(*l*) hybrid.

11. Draw a pistil of the wallflower before fertilization and also after the fruit is ripe. How many times longer is it?

What other changes have occurred?

What conclusion do you draw if the petals, sepals and stamens fall off before the fruit is ripe?

Remove one of the flat sides of the fruit and draw the seeds then exposed.

Where do the stalks of the seeds arise? How many rows of seeds are there?

12. Find out what other flowers in the garden are of the same pattern as the wallflower although different from it in colour.

13. Describe the wallflower plants in June, December or other month of the year when not in flower.

14. Describe in words the colours of the wallflowers provided.

15. Save some wallflower seed, and sow it yourself.

CHAPTER XII

THE DANDELION

Material required.

For individual examination.

Dandelions exhibiting the stages described in the chapter and pulled if possible by the pupils themselves just before the lesson.

Method of Study. We could not possibly better begin the study of this not much admired, but yet highly instructive plant, than under the auspices of the sun itself, some forenoon in early summer. Find a place where hundreds of its yellow discs light up the grass. Gather specimens at all stages. Take them inside and arrange them in the order of development.

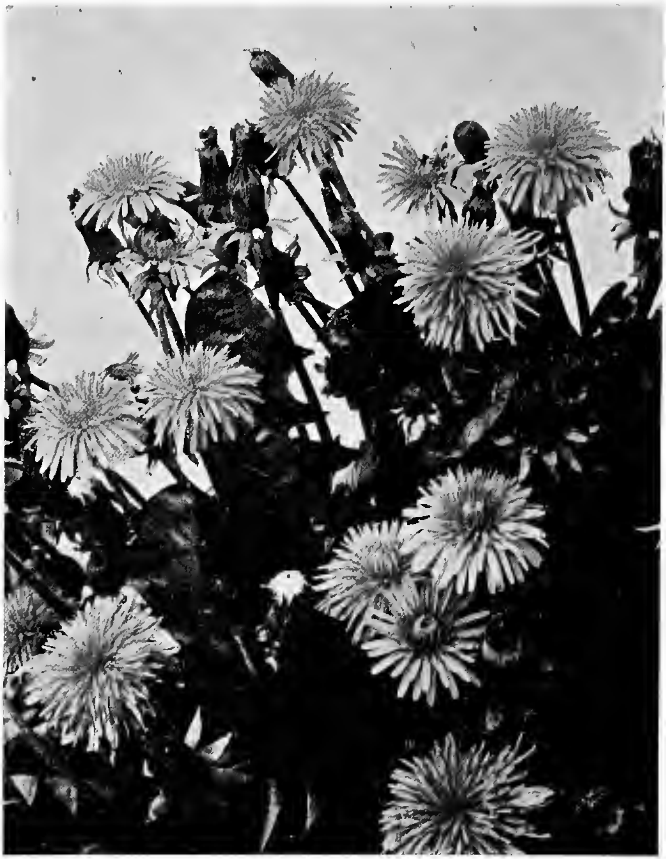

Fig. 20. Dandelions showing buds, "flowers" and the fruiting stage.

The Floral Drama. At one end of our line there is the fat, green, barrel-shaped bud, and at the other a white somewhat convex surface covered with dots and surrounded with a few withered bracts folded back against the long, bare stalk, which appears to have nothing to do but hold up its useless looking top. Everything seems to be at an end here, and so in truth it is. Yet upon this now deserted platform there has been enacted a drama of many acts, something like the "seven ages" of man. Here in the final act we have the dandelion *sans* everything. At first sight it seems difficult to see how the last condition could have been evolved out of the first. There is little sign of the bald head in the bud, and there is certainly not much of the bud in the bald head. Of course it is easily seen that the effete looking stalk is in reality the same stalk as supported the bud, and possibly the deflected withered bracts, though reduced in number and withered almost out of recognition, may be identified with the green organs which running upwards from the base of the bud to its apex formed a close-fitting tunic of green. Beyond this, and this is not very much, there seems nothing else to prove the evolution of the bud into the bald head, but we shall be convinced of it if step by step we spell out the story.

Flowering Phases. Somewhere between the bud and the bald head we shall certainly place the golden disc on which the straps of yellow from the centre to the rim are in countless numbers. Among the stages that are left we observe an open flower, which instead of consisting of yellow straps all the way to the centre, has there instead a mass whose barrel-shape recalls the unopened bud. This we therefore reckon an earlier stage. Now if we can find a bud that at one side has begun to fold its parts out and down, while at the other side it remains entirely as it was before, we have a stage that may readily be assigned a position next to the closed bud. So far, all is simple, but where shall we place in our series a closed dandelion which instead of bulging like the bud gradually narrows from base to apex? It may be suggested that here we have an early stage of the bud before it became tumid and ready to burst. This, however, is quite impossible, as it is already bigger than any of these fatter ones. Then note the curious mass resting somewhat loosely at its tip. This consists of a bundle of withered flowers, for the dandelion has twisted its showy yellow garments together and is in the act of rejecting them altogether in anticipation of a more airy, if less brilliant dress. As the yellow straps are here withered, this is evidently a stage beyond the fully opened yellow disc, which is the dandelion at the height of its glory. As far at least as colour is concerned the best is over. But what can be more perfect than its next form, when for the

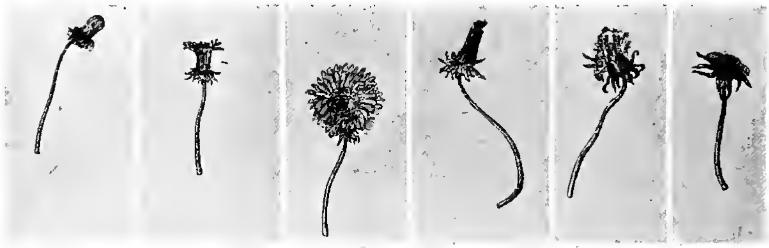

Fig. 21. Dandelion—flowering phases of the head. (From class drawings.)

last time it opens and is neither barrel-shaped, nor disc-shaped, nor conical, but an almost perfect sphere, with a large number of brown bodies at the centre, from each of which a fine radius runs out to spread from its end a portion of the light and airy periphery of the ball. It is easy to see where this stage comes in. Blow upon it and soon all that is left is the bald and dotted head which has already been given a place at the end of the series. Thus we have seven stages of the dandelion, the barrel, the beginning of the disc, the disc round the barrel, the perfect disc, the capped cone, the airy sphere and the deserted platform—a series of wonderful changes, from the dumpy bud to the brightness of the yellow disc and finally to the feathered fruits that fly away and leave nothing but a dot behind.

Structure of the "Flower." Of course one is apt to take it for granted that a dandelion is a flower just like a buttercup, or a rose or a harebell, and there seems to be some evidence for this apparently very natural view. Has it not got the circular shape so frequent in flowers, and the bright colour too? Are not the sepals round the outside just as they are in the buttercup, the rose and the harebell? Does it not close up at night like buttercups and many other flowers? This is all very well, but a little vague and unconvincing. Let us see what can be said for the opposite view. Even if we admit the apparent testimony of the shape and of the outer circle of green protective organs, there is certainly something wrong with the petals. By rights they should be in a circle inside the sepals, but instead of this they seem all over the face of the dandelion. Then there is no seed-box to be found in the usual place, namely at the centre, and no ring of stamens.

Even these facts may not seem to point very conclusively either way. So in order to get at a little more detail, we break the dandelion up and find that it very readily comes apart into a large number of small portions, each apparently complete in itself. One thing is clear at a glance. These structural units are all like each other. What the one is the others are. It will therefore be sufficient to examine a single unit. It is necessary, however, to be sure that we have got the whole of it, including the swollen portion at the foot, which is apt to get broken away from the rest.

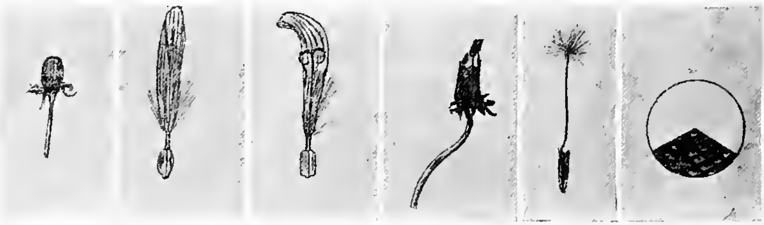

Fig. 22. Dandelion—flowering phases in single floret. (From class drawings.)

The object we are examining is certainly not a simple organ like a petal, but something complex and full of structural detail. Everything, however, is so clearly cut, so neat and delicate, that if anyone entertains the idea that the dandelion is a coarse plant, an inspection of one of these divisions of the head, whatever it be, goes a long way towards giving a different impression altogether. Now we must determine what it is, and might very well begin our inspection by making a large scale drawing. This will direct our attention to the minute details, none of which should be overlooked. By the time the sketch is finished, you may perhaps get the idea that it represents a whole flower. If so, you may try to identify either in the original or in your copy, the usual floral organs, sepals, petals, stamens, carpels. It is not necessary to look for them in the order named. It does not matter what is identified first. The main point is to identify something. So we begin with what we cannot fail to notice, the yellow strap-shaped organ, which is apt to be taken for a petal. Look at the tip of it. Here there are five teeth, and we suspect that we are looking at five united petals instead of one. The parallel lines that run down from between the teeth make this all the more likely. You may object that corollas are not usually strap-shaped, but circular or tubular. Just follow the parallel edges downwards and you will see how their union near the base makes the corolla, at that point at least, of an ordinary type.

Having disposed of the petals, look for something else. The swelling at the foot, what part of the flower is this? Most likely the seed-box. Then the curving yellow stigmas will be found in front of the corolla and the straight delicate style runs downwards and connects them with the box below. If you have any doubt about the last mentioned, open it and you will find the contents to be a solitary seed. That, of course, places the matter beyond dispute. Can we now find either the stamens or the sepals? Look just below the stigmas, and you will find a thickening of the style. Hold the lower part of the flower (for such it now certainly is) between the forefinger and thumb of one hand, and with the other take a similar hold of the stigmas and of a very small portion of the style. With a gentle pull the style comes away very easily, but the apparent thickening is left behind, and now appears as a tube from whose inferior end five thread-like stalks run down and unite with the corolla. This tube is evidently not part of the pistil, being in no way attached to either style, stigmas or ovary. If its position on the petals is not sufficient to suggest that the yellow tube is formed of a circle of united anthers, whose stalks are represented by the five delicate filaments mentioned above, the presence of pollen, revealed by touching one's sleeve with the yellow tube, will convince us that we have found the stamens.

Last of all we discover the sepals forming a hair-fringed tube arising from the top of the ovary and surrounding the lowest portion of the corolla.

Summary. After the identification of all these organs, no one can deny that this small portion of the dandelion, with its parts so beautifully fitted together, is really a flower, which in spite of its small size is complete in every way, and that the dandelion itself consists of a large number of these small flowers so arranged as to give the impression of a single large blossom. Flowers crowded together in this way are called **florets.**

Unity of the Inflorescence. The barrel-shaped bud then has a wonderful unity though it may contain perhaps a hundred florets. When it opens, they assume a radial position one after another in regular order along the spiral in which they are closely set. At the height of flowering, the whole hundred spread out to the sun at once, and at night all of them, with the same unanimity, fold together. The same hundred shuffle off their yellow robes at the same time. In the same protected chamber each matures its separate fruit, and

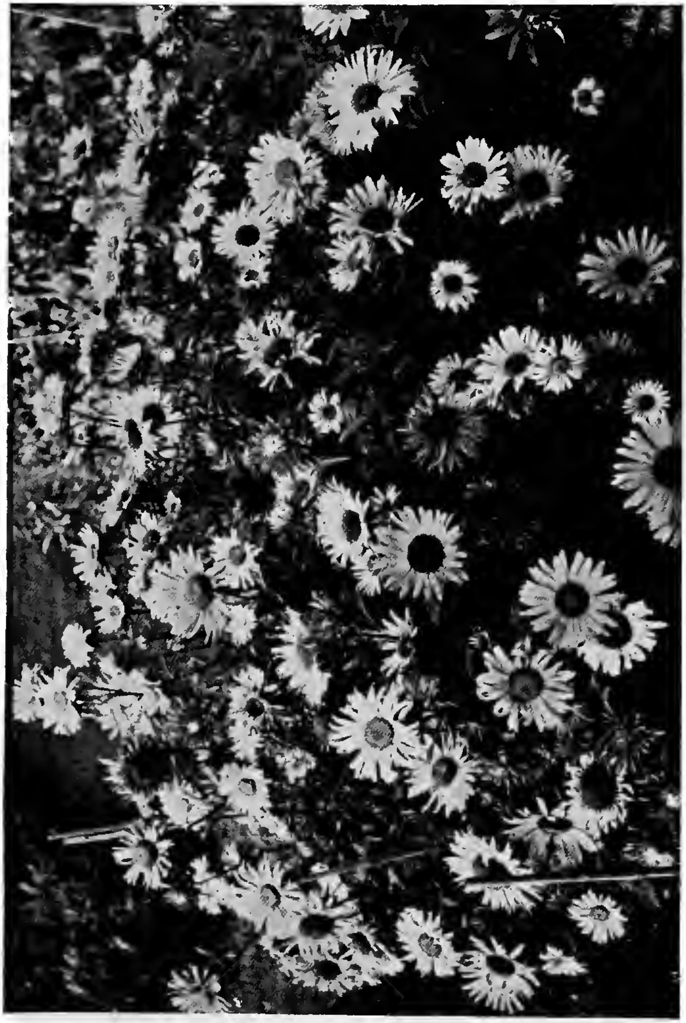

Fig. 23. Single asters. These are heads of flowers formed in the same way as in the dandelion.

when the time for dispersal comes, each fruit contributes its own quota of radius and surface to the general sphere. One must admire how throughout the phases of flowering so many different florets co-ordinate their activities and thereby produce a broad and unified result.

Floral Mechanism. It is not only the way the head as a whole is fitted together that is remarkable. In the individual flowers there are arrangements deserving of inspection. By making out a series of florets illustrating their development, we shall discover that the stamens are ripe before the stigmas, and may note how the elongating style brushes the pollen out of the tube formed by the anthers.

The fruit of the individual floret also calls for special notice, and we may experimentally test the efficacy of its floating apparatus, which consists of simple hairs spreading from the top of the stalk that connects them with the seed-vessel. By the growth of this stalk, which is really the calyx tube, the sepals emerge from their obscurity and become both prominent and useful.

A Hardy Species. We have seen, then, that the "flower" of the dandelion is really a collection of flowers, that is, an inflorescence, and of course, all its parts and arrangements help in the production of new plants. It is not, however, owing only to quantity of seed and the most effective way in which it is scattered that this species is so successful. It has another string to its bow in the individual's grip of existence. Few places come amiss to the dandelion. It will grow on the hillside. It is at home in the meadow. You find it almost unrecognisable under a coat of dust by a sun-scorched wayside. You will find it luxuriantly alive in the moist and shady corner. All places that the eye of heaven visits are to the dandelion ports and happy havens. The wind may blow, the sun may scorch, the dust may thicken, but the dandelion lives through it all. Not only does it keep the ground it has got its root fixed in, but it spreads its leaves flat on the adjacent surface and tries to annex more. The difficulty of clearing out dandelions is well known. You may behead the plant with a hoe and sever the rosette of leaves from the well-anchored root. It survives the shock, and from its stubborn underparts come perhaps two shoots instead of the one you have removed. It is the story of the dragon over again.

General Summary. As a thing of beauty the dandelion has hardly been praised as much as it deserves, nor has it perhaps been sufficiently appreciated as a subject of study, along with such favourites as buttercups and daisies. As a matter of fact it is one of the most interesting wild plants we have got, and whether we admire it or not, we must admit that, like not a few others of the family to which it belongs, it has remarkable perfection of structure, and has attained great success as a plant, having found its way to almost every part of the world.

EXERCISES

1. Describe the dandelion plant as it is to be seen growing.
2. Describe a single head in full bloom.
3. Make a representative series of drawings of the flowering phases from bud to bare head as described in the chapter.
4. Do the same with the single floret, greatly enlarged.

5. Make a special drawing of a single floret at its best, much enlarged, and with all the parts named.

6. Draw a single fruit, also much enlarged, and write a full description of it and of the seed it contains.

7. Examine the head of a daisy in detail and then compare it with the dandelion and the sunflower.

8. How does the inflorescence of the dandelion, that is, the flowering head, differ from and agree with the inflorescence of the wallflower?

9. Examine several florets at different stages and point out by what appearances we are able to determine whether the pollen is ripe before the stigmas or *vice versa.* Draw some conclusion from the conditions you find to exist. What conclusion would you draw if stigmas and stamens were both ripe at the same time?

10. Devise some simple experiment to ascertain the cause or causes of the opening and shutting of the dandelion.

11. The portion of the fruit that acts as a float is called the pappus. Experiment in order to determine its practical value. Put a number of separate fruits on a rough cloth and blow them along in a definite direction. Can you discover the use of any other external parts of the fruit?

12. Can you find a dandelion which has gone to seed under glass or other protection? Describe how the pappus is arranged.

APPENDIX

PLANT MATERIAL

A good supply of fresh material is essential. In the following list, which includes all that is needed for the lessons in the foregoing chapters, further particulars are given of the various plants, fruits and seeds discussed, with notes as to how and when they may be best obtained. The prices mentioned for some of the items are of course only approximate, and catalogues (seedsmen's and other) should be consulted.

Apples. Autumn. Per lb., 3*d.*

Avens (*Geum urbanum*). A common wild plant. Collect the ripe fruits in September. There are several cultivated species.

Beans (Taylor's Windsor). February to May. Per lb., 1*s.*

Broom. A common plant in Britain. Pods may be collected from July onwards. Seeds from agricultural seedsmen at about 1*s.* per lb.

Cabbages (smooth-leaved). Drumheads at their best during the winter months. Other varieties (such as Early York) at other seasons. Cannot be got with root during severe frost. Each, 1*d.* to 2*d.*

Candytuft (purple or white). A garden annual. May be sown in spring for autumn use. Seed, 8*d.* per ounce.

Cocoanuts : (*a*) as usually sold. Price according to size, 2*d.* to 4*d.* each. (*b*) complete with outer covering. To be specially ordered through fruit-dealer. Each, about 1*s.*

Crocus Corms. October and November. Por 100, 2*s.* Corms may be cheaper in January but cannot be expected to grow so well as those planted earlier and are not so good for dissection.

Dandelions. Common everywhere. Flowering through half the year but best in April, May, June.

Horse-Chestnut Buds. April or May.

Mustard (white). Seed, obtainable throughout the year, 2*d.* per ounce.

Snapdragon (*Antirrhinum*). July to September. Cut spikes, 1*d.* to 2*d.* per dozen. A well-known garden plant. Messrs Dobbie and Co. of Edinburgh have a fine selection of different varieties. Seed in packets, 3*d.*, 6*d.* and 1*s.* The plants may be propagated by cuttings as well as by seed. If by seed they are generally started under glass and planted out later. But if only a few dozen plants are required it may be convenient to purchase seedling plants from a nurseryman.

Messrs Dobbie and Co. of Edinburgh offer a few cultural hints in their catalogue of flower seeds:

"1. Sow in January in heat, transplant into boxes when large enough, grow on and transplant into cold frames end of March or beginning of April, where they will form dense tufts of roots. Lift carefully and plant out in beds early in May. These plants will begin flowering in July and continue until November.

2. Sow end of May and transplant when large enough into boxes or cold frames. Plant out into beds in September or October, and do not allow to bloom. A very large proportion of plants so treated will stand the winter and flower in June, giving long, beautiful spikes of bloom. This method is specially suited for the South of England, and for sheltered, well-drained situations in the North.

3. Sow in boxes in frames in July. Transplant when large enough into other boxes or specially prepared cold frames, where they should be wintered and planted out in April. If for blooming under glass, they should be potted up in September into small pots, grown on in a cold greenhouse, moved into larger pots in January, and shifted again in March into 5 or 6-inch pots, in which they will flower nicely in April and May.

We advise pinching all kinds of Antirrhinums grown for bedding when about 3 inches tall by simply removing 1 inch off the top with knife or thumb nail.

If long spikes are required for competition or conservatory decoration, the plants must not be pinched."

Spruce Fir Cones (for the seeds) may be gathered at any time and keep indefinitely. Fallen cones may have lost their seeds. Seeds of forest trees may be bought from Messrs Little and Ballantyne, Carlisle, or from Messrs Benjamin Reid and Co., 72, Guild Street, Aberdeen. Spruce seed, 5*s.* to 7*s.* 6*d.* per lb.

Tulips. Forced blooms in February and March 1*s.* per dozen. Outdoor blooms in May 6*d.* to 9*d.* per dozen. May be grown from bulbs (3*s.* per 100) to be planted in November or December either in garden ground or in pots.

Wallflower. Spring or early summer. Bunches of about 12 pieces, 1*d.* each from green-grocers. Easily grown from seed. Sow in April or May for flowers the following season. Transplant before winter into a sheltered sunny situation. Price of seed varies according to variety. Seed of common yellow wallflower about 1*s.* per ounce or 3*d.* a packet.

Willow-Herb. Pods in August and September. Use if possible the rose-bay willow-herb (*Epilobium angustifolium*) which grows wild in Britain, although not at all common. Easily grown in garden ground. Plants from 6*d.* each or seed may be bought. Failing *E. angustifolium*, the pods of *E. montanum*, which is plentiful everywhere, may be used instead. Evening Primrose (*Œnothera*) has a larger flower of similar type, and so has *Godetia.*

Fresh Specimens for Class use.

These may be obtained by post from the Botanical Supply Agency, Penparke, Aberystwyth.

Where there is a school garden it will be found convenient to grow some of the plant material required—particularly avens, candytuft, snapdragon, wallflower, willow-herb (*Epilobium angustifolium*), crocuses, tulips. A plentiful supply is thus assured and the specimens are at hand.

OTHER APPARATUS AND MATERIAL

Pots (4-inch) suitable for growing beans, mustard, tulips, etc. Each, 1*d.*, or 2*s.* 6*d.* per cast of 36.

Light-tight box. Any ordinary box of suitable size can be adapted to the purpose. A dark cupboard will do instead.

Soil for sowing or planting, ready mixed, 9*d.* a stone. For each 4-inch pot less than 1 lb. of soil is required. It may be prepared from two parts sand, one part leaf mould, one part loam, which must be mixed and passed through a quarter-inch sieve. These ingredients may be obtained from seedsmen, gardeners and nurserymen at small cost.

Cylindrical glass jars (battery jars). 6 to 8 inches high and 3 or 4 inches across, about 8*d*. each. An ordinary tumbler may be used instead.

Bell-jars (stoppered) of suitable size for covering germination experiments. Each, about 3*s*., or ask the York Glass Co., York, to quote price for "Winchester quart bottles" with the bottoms cut off as a cheap form of bell-jar.

Thermometers. Each, 1*s*. to 1*s*. 6*d*.

Plates or glazed flower-pot **saucers.**

Cotton wool, flannel or **sawdust** for germination experiment.

Summary of Cost of Material for Class of 24 pupils.

CHAP.		£	*s*.	*d*.
I.	Snapdragon	0	0	4
II.	Apples	0	1	6
III.	Pods of Willow-herb, etc.			nil
IV.	Cocoanuts	0	2	6
V.	Crocus Corms (100) ...	0	2	0
VI.	Cabbages	0	0	4
VII.	Mustard Seed (1 ounce)	0	0	2
	5 pots	0	0	5
	Soil (½ stone)	0	0	6
	Other items	0	1	2
VIII.	½ lb. Broad Beans ...	0	0	6
	12 pots	0	1	0
	Soil (1 stone)	0	0	9
IX.	Horse-Chestnut Buds ...			nil
X.	Tulips	0	2	6
XI.	Wallflower	0	0	4
XII.	Dandelions			nil
		£0	14	0

It is assumed that material for chapters III, IX and XII can be got without purchase. A few shillings should also be allowed for additional supplies that may be required in some cases.

Teachers in search of material will find it convenient to see the advertisements in the gardening magazines, several of which are named below.

NURSERYMEN, SEEDSMEN, ETC.

A very great many excellent firms are now engaged in the sale of seeds, bulbs and plants. In most cases it will be found possible to get everything required in the nearest county or market town. For the convenience of those living in the country a short list of well-known firms is added. Several of these publish beautifully illustrated catalogues. But where transplanting has to be done it is an advantage to procure the material from the nearest nursery gardens so that cabbage or other seedlings shall be out of the ground for the shortest possible time. Many firms of quite equal merit have necessarily been omitted for the sake of brevity.

Note. **B** = bulb dealers, **F** = florists, **N** = nurserymen, **R** = rose growers, **S** = seedsmen.

J. Backhouse and Son, Ltd., The Nurseries, York. **N.**

Barr and Sons, 11, 12 and 13 King Street, Covent Garden, London, W.C. **B. S.**

R. H. Bath, Ltd., The Floral Farms, Wisbech. **F.**

G. Bunyard and Co., Ltd., The Royal Nurseries, Maidstone. **N.** and Fruit Growers.

James Carter and Co., Raynes Park, London, S.W., and 237 High Holborn, London, W.C. **S.**

Clibrans, 10 and 12 Market Street, Manchester. **N.**

James Cocker and Sons, 130 Union Street, Aberdeen. **N. S. R.**

Alex. Dickson and Sons, Ltd., Belfast, Dublin, and Newtownards, Co. Down. **N. S. R.**

Dicksons, Ltd., Chester. **N. S.**

Dobbie and Co., 52 Moira Terrace, Edinburgh. **F. S.**

Kelway and Son, Langport, Somerset. **B. S.**

King's Acre Nurseries, Ltd., Hereford. **N.**

H. Merryweather and Sons, Ltd., The Rose Nurseries, Southwell, Notts. **N.**

Ryder and Son, Ltd., St Albans. **S.**

Sutton and Sons, Reading. **S.**

E. Webb and Sons, Ltd., Wordsley, Stourbridge. **S.**

J. C. Wheeler and Son, Ltd., Gloucester. **N. S.**

GARDENING MAGAZINES

Amateur Gardening, weekly, 1*d*. Messrs Collingridge, 148 Aldersgate Street, London, E.C.

The Garden, weekly, 1*d*. Country Life Ltd., 20 Tavistock Street, Strand, London, W.C.

Journal of the Royal Horticultural Society, irregular. Vincent Square, London, S.W. 7*s*. 6*d*.

Garden Life, weekly, 1*d*. Hatton House, Great Queen Street, London, W.C.

Fruit, Flower, and Vegetable Trades Journal, weekly, 1*d*. The Lockwood Press, 1 Mitre Court, London, E.C.

The Gardener, weekly, 1*d*. Cassell and Co., Ludgate Hill, London, E.C.

The Gardeners' Magazine, weekly, 2*d*. Messrs Collingridge, 148 Aldersgate Street, London, E.C.

Gardening Illustrated, weekly, 1*d*. 63 Lincoln's Inn Fields, London, W.C.

The Gardeners' Chronicle, weekly, 3*d*. Gardenors' Chronicle Ltd., 41 Wellington Street, London, W.C.

Gardening World. 37 and 38 Shoe Lane, London, W.C.

Scottish Gardener. 34 and 35 N. Frederick Street, Glasgow.

Country Life generally:—

Country Life, weekly, 6*d*.

The Field, weekly, 6*d*.

The Scottish Field, monthly, 6*d*.

The Ladies' Field. Southampton Street, London, W.C.

BOOKS

The following books will be found useful for reading or reference.

Nature Study.

Ludgate Nature-Study Readers, edited by J. C. Medd. Books 1 and 2, 1*s*. each. Book 3, 1*s*. 3*d*. Book 4, 1*s*. 6*d*. George Philip and Son, Ltd.

Object Lessons from Nature, by L. C. Miall, F.R.S. In two parts at 1*s*. 6*d*. each. Cassell and Co., Ltd.

House, Garden and Field, by L. C. Miall, F.R.S. 6*s*. Edward Arnold.

Round the Year, by Professor L. C. Miall, F.R.S. 3*s*. 6*d*. Macmillan and Co., Ltd.

Nature Studies, by G. F. Scott Elliot. 3*s*. 6*d*. Blackie and Son, Ltd.

School Lessons in Plant and Animal Life, by John Rennie, D.Sc. 4*s*. 6*d*. University Tutorial Press.

The Great World's Farm, by Selina Gaye. 5*s*. Seeley and Co.

The Book of Nature Study, edited by J. Bretland Farmer, D.Sc., F.R.S. 6 vols., at 7*s*. 6*d*. each. The Caxton Publishing Company.

Nature Study and the Teaching of Science in Scottish Schools [Cd. 4024]. 3*d*. Wyman and Sons.

Weeds, by R. L. Praeger. 1*s*. 6*d*. net. Cambridge University Press.

The Story of Our Trees, by M. M. Gregson. 2*s*. 6*d*. net. Cambridge University Press.

General Botany.

Botany. A text-book. By D. Thoday, M.A. With 205 figures. 5*s*. 6*d*. net. Cambridge University Press.

Botany, or The Modern Study of Plants, by Marie Stopes, D.Sc. 6*d*. net. T. C. and E. C. Jack.

Plant Life, by J. Bretland Farmer, D.Sc., F.R.S. 1*s*. 3*d*. net. Williams and Norgate.

Elementary Studies in Plant Life, by Fritsch and Salisbury. 2*s*. G. Bell and Sons, Ltd.

An Introduction to the Study of Plants, by Fritsch and Salisbury. 4*s*. 6*d*. net. G. Bell and Sons, Ltd.

Botany, by Joseph W. Oliver. New edition revised and enlarged by W. B. Grove. 2*s*. Blackie and Son, Ltd.

A Practical Introduction to the Study of Botany, by J. Bretland Farmer. 2*s*. 6*d*. Longmans, Green and Co.

The Student's Introductory Handbook of Systematic Botany, by Joseph W. Oliver. 4*s*. 6*d*. Blackie and Son, Ltd.

A Text-Book of Botany, by Dr E. Strasburger. 18*s*. net. Macmillan and Co., Ltd.

Kerner's Natural History of Plants. 2 vols., 30*s*. net. Blackie and Son, Ltd.

Ecology.

Life Histories of Common Plants, by F. Cavers, D.Sc. 3*s*. University Tutorial Press.

Open-Air Studies in Botany, by R. Lloyd Praeger. 6*s*. net. Charles Griffin and Co., Ltd.

Types of British Vegetation, by A. S. Tansley. 6*s*. net. Cambridge University Press.

The Journal of Ecology. Cambridge University Press.

Practical Physiology.

The Food of Plants, by A. P. Laurie. 1*s*. Macmillan and Co., Ltd.

Seasonal Botany, by M. O'Brien Harris, D.Sc. 8*d*. Blackie and Son, Ltd.

Botanical Experiments for Schools, by Ida H. Jackson. 1*s*. 6*d*. Blackie and Son, Ltd.

Experimental Plant Physiology, by Lucy E. Cox. 2*s*. net. Longmans, Green and Co.

Practical Plant Physiology, by Frederick Keeble, Sc.D. 3*s*. 6*d*. G. Bell and Sons, Ltd.

Practical Physiology of Plants, by Darwin and Acton. 3rd ed. 4*s*. 6*d*. Cambridge University Press.

Experiments with Plants, by W. J. V. Osterhout, Ph.D. 5*s*. 6*d*. net. The Macmillan Company.

Practical Plant Physiology, by Dr W. Detmer. 2nd ed. 12*s*. Allen and Co., Ltd. (A standard work.)

Identification and Description of Species.

Wayside and Woodland Blossoms, by Edward Step. Two Series, 6*s*. each. Frederic Warne and Co.

Wild Flowers, by Macgregor Skene. 6*d*. net. T. C. and E. C. Jack.

Flowers of the Field, by the Rev. C. A. Johns. 7*s*. 6*d*. net. George Routledge and Sons, Ltd.

How to study Wild Flowers, by the Rev. George Henslow. 2nd ed. 2*s*. 6*d*. net. R.T.S.

A School Flora, by W. Marshall Watts, D.Sc. New ed. 3*s*. 6*d*. Longmans, Green and Co.

The Botanist's Pocket-Book, by W. R. Hayward. New ed. 4*s*. 6*d*. George Bell and Sons, Ltd.

Handbook of the British Flora, by Bentham and Hooker. 9*s*. L. Reeve and Co.

Notes on the Life History of British Flowering Plants, by Lord Avebury. 15*s*. Macmillan and Co., Ltd.

Gardening and Rural Science.

Gardening for the Ignorant, by Mrs C. W. Earle and Ethel Case. 1*s*: Macmillan and Co., Ltd.

Gardening, by L. Williams. 1*s*. net. Thomas Nelson and Sons.

All about Gardening, by Harry Roberts. 3*s.* 6*d.* net. Ward, Lock and Co., Ltd.

English Flower Garden, by W. Robinson. 15*s.* net. John Murray.

Studies in Gardening, reprinted from *The Times*. 1*s.* net.

Concise Handbook of Garden Flowers, by H. M. Batson. 3*s.* 6*d.* Methuen and Co.

Pictorial Practical Bulb Growing, by W. P. Wright and H. J. Wright. 1*s.* Cassell and Co., Ltd.

Pictorial Practical Gardening, by W. P. Wright. 1*s.* Cassell and Co., Ltd.

Educational School Gardening and Handwork, by G. W. S. Brewer. 2*s.* 6*d.* net. Cambridge University Press.

Principles and Practice of School Gardening, by Alexander Logan. 3*s.* 6*d.* Macmillan and Co., Ltd.

Tillers of the Ground, by Marion I. Newbigin, D.Sc. 1*s.* 6*d.* Macmillan and Co., Ltd.

A First Book of Rural Science, by J. J. Green. 1*s.* 6*d.* Macmillan and Co., Ltd.

Lessons on Soil, by E. J. Russell, D.Sc. 1*s.* 6*d.* net. Cambridge University Press.

A Book of Simple Gardening, especially adapted for schools, by D. Lowe. 2*s.* net. Cambridge University Press.

The Publishers of *The Gardeners' Chronicle* issue a catalogue of gardening books and also offer to procure the books and quote prices at which they can be sent post free.

SPECIAL REFERENCES

For further information on the subjects of some of the foregoing chapters the following may be consulted:

Apples. *Apples and Pears*, by George Bunyard.

Cabbage. "Cabbages and Turnips," pp. 183 to 192 in *Round the Year* (see above, p. 141). *One and All Garden Book*, no. 25.

Cocoanut. Article "Cocoa-nut," Vol. III, *Chambers's Encyclopaedia*. *The Coco-nut*, by Edwin B. Copeland.

Crocus Corms. "Spring Crocuses," pp. 64 to 73 in *Round the Year* (see above, p. 141).

Dandelions. "The Dandelion," Lesson XIII in Part I of Professor Miall's *Object Lessons from Nature*. Cassell and Co., Ltd.

Dispersal of Seed. "Seed-scattering," Chapter XVII in *The Great World's Farm* (see above, p. 141).

Horse-Chestnut. "Buds," pp. 121–137 in *Round the Year* (see above, p. 141). *Trees*, by H. M. Ward. 5 vols., 4*s*. 6*d*. each. Cambridge University Press.

Snapdragon. *Sweet Peas and Antirrhinums*, by William Cuthbertson. London, James Clarke and Co., 13 and 14 Fleet St., E.C., 1915. Price 1*s*. net. See also *Journal of the Royal Horticultural Society*, vol. xxxix, part 3, April, 1914.

Tulips. *Tulips*, by Rev. Joseph Jacob.

Wallflower. Pp. 65–66 in *How to Study Wild Flowers* (see above, p. 142).

SUGGESTIONS FOR ADDITIONAL OR ALTERNATIVE LESSONS

CHAP.	
I.	(Snapdragon)—hollyhock, sunflower.
II.	(Apple)—hips and haws of wild rose, melon.
III.	(Seed Dispersal)—other methods of propagation—(1) runners (strawberry), (2) tubers (potato).
IV.	(Cocoanut)—acorn, date.
V.	(Crocus Corms)—sections of stems.
VI.	(Cabbage)—brussels-sprouts, branching of trees.
VII.	(Germination)—artificial propagation (1) by stem cuttings, (2) by division of leaf.
VIII.	(Broad Beans)—comparison of various seedlings—scarlet runner, castor oil, sunflower, wheat.
IX.	(Horse-Chestnut Buds)—beech, sycamore.
X.	(Tulip)—comparison for number and symmetry of parts with marsh marigold or buttercup and with dead nettle.
XI.	(Wallflower)—pollination arrangements in broom, campion.
XII.	(Dandelion)—inconspicuous flowers—plantain, dog's mercury.

Microscope. The use of the compound microscope is in no way essential to these lessons which are intended for naked-eye work and do not even stipulate for the use of lens, mounted needle and sharp knife by every scholar. These latter will greatly improve the attainable standard of work. If a microscope is available it may as well be used for a few peeps into Nature's wonderland as suggested on pp. 59, 113 and 122.

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